Popular Astronomy

Vol. LI, No. 5 MAY, 1943 Whole No. 505

The Story of Pleione*

By OTTO STRUVE

1. Conspicuous to the naked eye in the winter sky is a hazy patch of light, near the zenith early in the evening at this time of the year, and containing some five or six stars which are easily visible. This patch of light is formed by a cluster of stars—the Pleiades. The name is of ancient origin and probably comes from the Greek word πλειος, meaning "full" or "many." As a matter of fact, the Pleiades consist of many hundreds of individual stars covering an area about 36 times that of the full Moon. The brightest star—Alcyone—is of the third magnitude. The faintest members of the group are below the limit of our best telescopes. These stars all move through space with the same speed and in the same direction. Although the stars appear to be closely packed on a photograph, their average distances apart are several light years. The distance of the cluster is 500 light years, and a star of the intrinsic brightness of the Sun would appear as if it were of the tenth magnitude. The brighter members of the cluster, say of the fifth apparent magnitude, are therefore 100 times more luminous than the Sun.

Long exposures bring out an intricate network of bright nebulosity enveloping the cluster. The wisps of nebulosity are not gaseous, since they show a pure reflection spectrum of the stars involved in them. Recent studies tend to show that they consist of dust particles whose diameters are of the order of 10^{-5} cm. The total thickness of these dust clouds is very great and their absorbing power for stars behind is quite appreciable.

2. Few star groups have aroused as much interest in ancient times as have the Pleiades. We are told the myth that the giant Atlas, who carries the world on his shoulders somewhere in Northwest Africa, married the nymph Pleione. They had seven daughters: Alcyone, Merope, Maya, Electra, Taygeta, Asterope, and Celaeno. The seven girls were so beautiful that the mighty warrior Orion started to pursue them with his attentions, much to their discomfort. Hence they appealed to Jupiter, who changed them into doves and allowed them to fly into the sky and find a refuge among the stars.

There is an ancient tradition that one of the stars in this group has been lost or has become dim. This has given rise to numerous stories

*Lecture delivered at the Cincinnati Astronomical Association on February 19, 1943.

of the "lost Pleiad" which were current all over the world. They are found in ancient Greece and in Italy, among the natives of Australia, in the Malays and in Borneo, among the negroes of the Gold Coast and in the folk songs of the Russian peasants. These stories are so widespread that it seems possible and even probable that there has actually been a decline in the brightness of a prehistorically conspicuous member of the cluster. Aratos wrote:

> "As seven their fame is on the tongues of men
> Though six alone are beaming on the eye."

Unfortunately it is impossible to say which star is the lost Pleiad. A few years ago the entire story was largely being discounted by the astronomers and attributed to superstition and misinformation. But if we consider the question more thoroughly there appears to be no reason how such a story could have originated without some factual basis. Although the ancients were not particularly interested in the phenomena of the fixed stars, they recorded with precision the appearances of novae, and they carefully observed those objects which had a mythological significance. The Pleiades were associated in their minds with the heavy rains of autumn, and it is probable that they observed them frequently and had a good record of the normal appearance of the group.

The principal stars of the cluster, their apparent magnitudes, and spectral types, are as follows:

1. Alcyone	3.0	B5p
2. Atlas	3.8	B8
3. Electra	3.8	B5p
4. Maya	4.0	B5
5. Merope	4.2	B5
6. Taygeta	4.4	B5
7. Pleione	5.2	B8p
8. Celaeno	5.4	B5
9. Asterope	5.8	B8

All nine stars are brighter than the sixth magnitude, and should be normally visible to the unaided eye. But, in fact, the clustering of the stars and their proximity to the bright third-magnitude Alcyone renders the fainter ones fairly difficult objects to see, except for very good eyes. Exceptionally keen observers, like Maestlin, the teacher of Kepler, are reported to have seen as many as fourteen stars. Eleven of them were mapped previous to the invention of the telescope. However, under normal conditions only six stars are easily seen, namely, Alcyone, Atlas, Electra, Maya, Merope, and Taygeta. Incidentally, the identifications of the stars now associated with the ancient names are of relatively recent origin. Atlas and Pleione were not named by the ancients at all, nor is it certain that they associated each of the remaining seven names with any particular stars. In fact, the identifications as we now use them are due to Riccioli, in the 17th century. Ptolemy observed four members of the cluster, but it is probable that Alcyone was not one of

them. In fact, there is strong reason to believe that until the tenth century Alcyone was not as bright as it is now.

The lost Pleiad was thought by some ancient writers to have been struck by lightning. Others thought that it had been removed into the tail of Ursa Major, where as Alcor it rides on top of Mizar. Ovid thought that Electra, the wife of Dardanus, the founder of the city of Troy, was so overwhelmed with grief after the fall of the fortress that she veiled her head in order not to witness the destruction of the city.

A different story was prevalent among the Iroquois Indians. They thought that there were once seven little Indian boys, who danced in the woods and sang the song of the stars. On one occasion the stars beckoned to the little boys and they followed the signal and went up into the sky. One of the boys became homesick and started crying, covering his face. This left only six visible in the sky.

Some fifty years ago Professor E. C. Pickering suggested that the spectrum of Pleione in some respects resembled that of the star P Cygni, which at one time was much more brilliant than now. If Pleione had diminished in brightness as P Cygni had, it could well have accounted for the seventh, the lost, Pleiad. It is not possible to make further progress with this historical problem. But we shall see that modern information strongly supports the view that the Pleiades form a group of very unusual stars, that some of them vary in spectrum and in light, and that Pleione is at present the most interesting member of the cluster.

3. At first sight we detect nothing very unusual about Pleione. It is a blue star, with a temperature of 15,000°, an apparent magnitude of 5.2 and an absolute magnitude of —1.0 (this would be its visual magnitude if it were located at a distance of 10 parsecs or 33 light years). The radius of Pleione is about five times that of the Sun; it belongs to the main sequence of stars in the Russell diagram. In fact, its characteristics are perfectly normal for a B8-type star, as it had been classified by Miss Cannon at Harvard.

The first slightly unusual bit of information about Pleione came in 1888, when E. C. Pickering announced that on Harvard objective prism plates Hβ of hydrogen appeared as a bright emission line and not as an absorption line of the kind observed in the rest of the brighter Pleiades. This result was later substantiated by Professor Keeler at the Lick Observatory and by Miss Maury at Harvard. In 1914 H. W. Jung examined several photographs of Pleione made by Hartmann with the spectrograph in Potsdam and found that while in 1903 the bright line was still present, in 1906 it had become replaced by an ordinary, broad absorption line. The disappearance had been noticed as early as 1905 by Professor E. B. Frost at the Yerkes Observatory. Pleione thus furnished the first well-established case of complete disappearance of emission lines, and it was for many years regularly cited as a classical example of a variable Be star.

In October, 1938, D. B. McLaughlin and O. Mohler independently discovered the reappearance of emission lines at Hα and Hβ. Since then the emission has been observed at several observatories. It is strong at Hα and rather weak at Hβ, and there have been small changes in the appearance of the lines. But fundamentally, Pleione has, during the past 4½ years, reverted to its original character of a bright-line object.

We are thus concerned with three stages of the star: (1) the bright-line stage prior to 1903, (2) the absorption-line stage from 1905 to 1938, and (3) the new bright-line stage since 1938.

In principle we associate an ordinary absorption line spectrum like that of the second stage with a normal stellar atmosphere, a few hundred kilometers in thickness which absorbs the continuous light of the photosphere underneath. The presence of bright lines is believed to be caused by a large mass of nebulous matter forming a shell around the star. The lines produced in such a shell are of the emission type and superimpose themselves over the normal absorption lines of the reversing layer. We therefore conclude, in a general way, that before 1905 and again after 1938, Pleione had a nebulous shell, while in the interval of 33 years between these two dates it had no such shell.

Although the disappearance of the bright lines in 1905 constituted a discovery of major proportions which created a great stir among astronomers, the reappearance in 1938 was by no means unexpected. Astronomers had during the intervening years discovered many other Be stars with variable emission lines. In fact, it is now considered probable that all or nearly all B-type stars with emission lines have variable spectra: in some (like Pleione and κ Draconis) the bright lines appear and disappear, the individual cycles lasting from a few years to some tens of years; in others (like ϕ Persei) the emission lines are double, and the relative intensities of the two components undergo marked variations.

While Pleione underwent the changes which I have described, there were also recorded small but unmistakable changes in brightness. Dr. Calder at Harvard, using a photoelectric photometer, found in 1937 that Pleione had decreased in brightness by about one-sixth of a magnitude. I have just learned that M. Mündler at Heidelberg found an appreciable increase in brightness (by 0.15 mag.) between 1939 and 1942, without finding a change in color. Earlier, in 1939, E. J. Williams had detected a slight reddening. It is very unfortunate that because of the war no attempt has been made to observe the brightness and the color of Pleione systematically. Since 1938 this star has undergone some of the most remarkable spectroscopic changes on record.

4. During the interval of 33 years when the spectrum of Pleione was devoid of bright lines it resembled the spectra of many other helium stars. The absorption lines of neutral helium and ionized magnesium

were exceedingly broad and hazy and could be seen only on the best spectrograms. The hydrogen lines were strong and broad, but the central portions of each line gave the appearance of being rounded off, as though the plate had been taken badly out of focus. In reality, of course, the focus was perfect, as could be ascertained from the appearance of the comparison spectrum of iron and titanium sparks.

The great widths of the lines of helium and magnesium—about 10 angstrom units—cannot be reproduced in the laboratory under ordinary conditions. The only physical condition known to produce broad lines in the laboratory is very high pressure—much higher than is known to exist in the tenuous atmospheres of the stars. But even if we did not know the pressures in the stars we should still be able to exclude this explanation. A pressure which would suffice to broaden the lines of helium to the observed extent would hardly affect the magnesium line and would leave the lines of other metals completely narrow. The observations, on the other hand, show that the amount of broadening is the same for all lines.

If the broadening is not produced by a physical cause, it must be due to Doppler effect. We observe light from the entire visible hemisphere of the star. If the star rotates or expands, different regions of the apparent disc will have different radial velocities, and the composite picture of all parts of the disc will be a blurred spectral line, whose over-all width will correspond to the entire range of radial velocity components from all parts of the disc.

This hypothesis can be tested if we remember the fundamental formula of the Doppler effect, namely, that the displacement of a spectral line by a radial velocity, v, is proportional to v and inversely proportional to the wave-length of the line, λ. A red line will be widened twice as much as an ultra-violet line, if the widening is measured in angstrom units. For example, if the widening of 10A, referred to above, was measured in a red line, the widening of an ultraviolet line should be only 5A. This test has been applied to several stars which are similar in their spectral characteristics to Pleione. The conclusion is that the Doppler formula is exactly obeyed. There can be no doubt that the line broadening is caused by the superposition of elements which have different Doppler displacements.

But are we dealing with rotation, or expansion, or contraction, or turbulent motions within a stellar atmosphere? All such effects would produce broad spectral lines, and would at the same time conform to the Doppler formula.

Fortunately, there are good reasons to exclude expansion and contraction and also turbulence. In an expanding or contracting atmosphere the shape of the resulting line is unsymmetrical. A relatively simple geometrical computation (first carried out by Shapley and Nicholson at Mount Wilson) shows that the line should extend from

the normal, or zero, position of the line to $\Delta\lambda$ corresponding to the velocity of expansion (or contraction) and should be deepest at or near $\Delta\lambda$, becoming more and more shallow as the zero position, $\Delta\lambda = 0$, is approached. Such lines are sometimes observed in novae and in some other stars known to expand. They are not like the lines of Pleione, which appear symmetrically broadened on both sides of the zero position, with the deepest absorption in the middle. Such lines are best described by the word "dish-shaped," which was coined by C. T. Elvey many years ago when he was engaged in the photometric measurement of stellar absorption lines.

We can also eliminate from consideration the type of broadening which is caused by turbulent motions. Such motions produce broad lines which are very deep in the middle, not dish-shaped lines which are shallow. Stars like ϵ Aurigae, 17 Leporis, and δ Canis Majoris have such lines and from a study of their spectra we can determine the characteristic features of turbulent stellar atmospheres. Pleione prior to 1938 did not possess these features.

This leaves us with two possibilities: axial rotation and convection currents. The latter is excluded by a study of close spectroscopic binaries in which the rotational velocities are known from the orbital periods and the dimensions of the stars. The final conclusion is that Pleione and other stars with dish-shaped absorption lines have very rapid axial rotations. A point on the equator of Pleione rotates with the tremendous velocity of nearly 300 km/sec.

5. In 1938 some kind of catastrophe took place in Pleione, and the bright lines of hydrogen reappeared, after an absence of 33 years. Simultaneously, there appeared in the spectrum a number of narrow absorption lines of various ionized metals: iron, titanium, nickel, chromium, vanadium, scandium, etc.

These lines were at first rather weak. But they gradually increased in strength, until the metallic absorption spectrum became almost a replica of the spectrum of α Cygni. But there were two small and rather inconspicuous, yet exceedingly important, differences. One line of ionized magnesium and five lines of ionized silicon, all of which are strong in α Cygni, remained very weak and somewhat diffuse in Pleione.

This small difference between the two spectra would probably have remained unnoticed, were it not for the fact that I had found, a few years ago, that the atoms of ionized magnesium and silicon possess a most remarkable property, which renders them extremely useful in astrophysical research. When these atoms form an absorbing layer, they reduce the amount of light passing through it by a fraction which depends not only upon the number of atoms present, but also upon the intensity of the radiation passing through the layer. This property is rather unusual. A piece of smoked glass, for example, reduces the amount of light by a fixed fraction, irrespective of the intensity of the

light observed. But if we could make a screen of some substance which is sensitive to light, for example silver chloride, the absorption of the screen would be relatively insignificant if the source of light seen through it is dim, and would be very powerful if the source is brilliant. The ions of magnesium and silicon act like silver chloride: if they happen to be located on the surface of a star their absorbing power is very great, and the absorption line which is formed by them is strong. But if they happen to be somewhere in space, far above the star's surface, their absorbing power is weak and the line produced by them is faint.

The theoretical explanation of this phenomenon leaves no doubt that it is operating in Pleione. The lines of magnesium and silicon are weak not because there is little magnesium and silicon in the absorbing layer, but because the layer is far above the surface of the star. We can go one step further. We can actually compute in terms of Pleione's radius how high above the surface the layer is located. The result is three times the radius of Pleione.

The catastrophe in 1938 led to the formation of a layer or shell at a distance of three times the radius of the star above its surface. This result helps to explain another mystery. The absorption lines of the shell are narrow, those of the original star are broadened by rotation. Evidently the minute section of the shell which appears to us projected upon the apparent (yet unresolved) disc of the star does not rotate fast enough to produce appreciable broadening of the lines. From the geometry of the problem we conclude that if the shell shared the angular velocity of the star, the rotational broadening of the lines of the shell would be equal to that of the original star lines. The fact that the observed shell lines are narrower shows that the angular velocity of the shell is smaller than that of the star. How much smaller may be estimated from the widths of the hydrogen emission lines. These are probably produced in the same shell as the narrow metallic absorption lines, but while the latter by virtue of their nature are produced only by those atoms which are in front of the star's disc, as seen from the Earth, the latter are produced by all atoms of the shell, including its lobes which extend beyond the area of the star's disc, and which would show the entire Doppler effect of the shell's rotation.

The width of the bright hydrogen beta line, unsymmetrical though it is, corresponds to a rotational velocity of perhaps 100 km/sec, or somewhat more. Since we estimated the rotational velocity of the star itself to be about 300 km/sec at the equator, we conclude that the shell rotates three times slower in kilometers per second. And since the radius of the shell is about three or four times that of the star we conclude that the linear velocity of rotation of the shell is inversely proportional to its radius.

This law, which we have derived here empirically from our observations is well known in theoretical mechanics. It is there designated

as the law of conservation of angular momentum.

6. It is tempting to suggest that the catastrophe of 1938 had some connection with the rapid axial rotation of Pleione. If the rotational velocity at the equator of a star is very great the centrifugal force of this rotation may surpass the force of the star's attraction, and when that takes place the outer equatorial gases of the star must be catapulted into space, where they would form a rotating ring—somewhat like the rings of Saturn.

The acceleration due to gravity can be computed if the mass and the radius of the star are known. The acceleration of the centrifugal force depends upon the velocity at the equator and the radius. The two are equal if the velocity at the equator is

$$v = 440 \sqrt{(M/R)} \text{ km/sec.}$$

We already know that $R = 3R_\odot$. If we assume, for lack of better data, that the mass $M = 3M_\odot$, we find that the critical velocity is

$$v = 440 \text{ km/sec.}$$

This is about 50 per cent greater than the value found from the observations (300 km/sec), but we have neglected various factors in the computation, for example, the effect of radiation pressure in reducing the effective force of gravity.

It is doubtless permissible to conclude that the rotation of Pleione is so rapid that the equatorial regions are near the point of break-up. The best hypothesis we can make is that equatorial break-up actually took place in 1938.

7. It is instructive to apply the proposed hypothesis to other stars. We know several hundred helium stars with bright lines, and among these there are perhaps two or three dozen of stars whose spectra show the same kind of shell absorption as Pleione does at the present time.

Let us consider first the ordinary helium stars without bright lines. For several hundred of them the equatorial velocities of rotation have been determined, and we can present the material in a table which shows the percentage of stars for each of four groups arranged according to the observed velocity of rotation, as determined from the lines of helium and magnesium:

Group	*Vel. of Rot.*	*Per Cent of all Helium Stars*
I	0-50 km/sec.	27
II	50-100	53
III	100-150	15
IV	150-200 and more	5

It is clear that this distribution is affected by the fact that not all axes of rotation are at right angles to the line of sight. If some are inclined by an angle i, then the observed velocity is not the true equatorial velocity, but rather the foreshortened component of it:

$$V_{observed} = V_{true} \cdot \sin i$$

Let us assume for the moment that all stars rotate with identical velocities of 200 km/sec. Then those velocities which are observed to be between 0 and 50 km/sec correspond to angles of inclination between 0° and 15°, etc. We can compute the predicted distribution of percentages if we make the reasonable supposition that the directions of stellar axes are distributed at random. Of course, we must remember that small values of the angle are much less frequent than angles in the vicinity of 90°, because there is only one possible way in which an axis can be oriented to give $i = 0°$, but there are an infinitely large number of orientations giving $i = 90°$.

The computation gives us the following predicted distribution:

Group	*Vel. of Rot.*	*Angle i*	*Pred. Per Cent of Stars*
I	0-50 km/sec.	0°-15°	4
II	50-100	15°-30°	14
III	100-150	30°-50°	25
IV	150-200	50°-90°	57

The two distributions are totally different, and we must conclude that not all helium stars rotate with speeds of 200 km/sec, but that there are many stars whose true rotations are much smaller.

If we next consider only those helium stars which are known to have bright lines—some hundreds in number—and construct a table similar to that made above for all helium stars, we find percentages which agree fairly closely with the predicted values:

Group	*Per Cent of Be Stars*
I	3
II	20
III	27
IV	50

These values are not exact, but they suffice as illustrations. They unquestionably show that the Be stars constitute a selection of helium stars whose true velocities of rotation are very large. The remaining spread of true velocities must be quite small, and the observed cases of stars having small observed rotations are easily accounted for by the hypothesis of random distribution of axes. Incidentally, this last table does not include those Be stars which are supergiants, but this limitation is not very serious, because the vast majority of Be stars are objects of moderate luminosity.

Finally, we can pick out from the Be stars those which show pronounced shell absorption. There are not many, yet the result is fairly convincing: all shells for which the rotational velocity of the original star can be determined have large values:

Group	*Per Cent of Shell Stars*
I	0
II	0
III	0
IV	100

We conclude that the shells are such Be stars which have their axes

oriented at right angles to the line of sight. This is what we should have expected if the shells are really ring-like structures located in the equatorial planes of rapidly rotating stars.

It must be admitted that the last table is slightly deceptive. In the first place, the number of objects having shell spectra is not very great, and one might wonder whether we have accidentally observed only those which happen to be in group IV. In the second place, we discover the existence of a shell by means of two spectroscopic criteria: the abnormal weakness of the lines of ionized silicon and magnesium and the presence of broad, rotationally distorted lines of helium. The first criterion is independent of the manner in which the table was organized, but the second is not. On the other hand, we might have introduced, in support of the ring hypothesis, the remarkable discovery made last year by A. H. Joy at Mount Wilson of a bright-line star which happens to be an eclipsing variable. During the partial phases of the eclipse, first one-half of the bright line was observed to disappear and then the other, just as though the eclipsing companion had first passed in front of one lobe of a rotating gaseous ring and then in front of the other. But it is possible that Joy's star is not in all respects similar to the ordinary Be stars. Considering the entire evidence I believe that the conclusions which I have presented are fully justified.

8. It would be wrong if on the strength of the preceding discussion we should draw the following conclusions:

(a) All helium stars whose velocity of rotation is of the order of 200 km/sec have emission lines, and

(b) All emission-line (Be) stars whose axes are at right angles to the line of sight have shell-absorption spectra.

Both conclusions are untrue, and we must admit that rapid rotation alone does not always give rise to emission lines, and that the existence of emission lines is not always sufficient for observing shell absorption if the orientation is favorable.

It is clear that some important contributing factor has been overlooked. Rotation is necessary to produce a shell, but it is not sufficient. We have no obvious clue in the observations, nor does theory help us. Where there are no obvious clues, we must begin to search systematically for less obvious ones.

It has been noticed that some well-known shell spectra show variable radial velocities. The famous star of β Lyrae, whose pin-wheel shell is somewhat similar to the shells we are concerned with here, is a binary. Several other shells have long-period oscillations of radial velocity. Two of the best observed, ϕ Persei and ζ Tauri, have almost identical periods of a little more than four months.

It seemed important to know whether the radial velocity of the shell of Pleione is constant. I have just completed the measures of more than 70 spectrograms secured at Yerkes and McDonald Observatories.

There are unmistakable waves in the velocity curve with a range of 10 km/sec, which repeat themselves every four months. I cannot yet say whether the phenomenon is strictly periodic, as in ϕ Persei and ζ Tauri, or somewhat irregular, as in 17 Leporis. Nor do I have any idea as to the meaning of the variations in velocity. For all I know, Pleione may be a spectroscopic binary. Before the shell made its appearance, a range of 10 km/sec would not have been noticed, since the broad star lines could not be accurately measured. On the other hand, it is also possible that the observed variations in velocity originate only in the shell and do not affect the star at all.

Our complete lack of understanding of this extra factor in the production of Pleione's shell constitutes one of the most tantalizing riddles of modern stellar spectroscopy.

9. It is of interest to compare Pleione to other members of the cluster. I have therefore made a study of the equatorial rotational velocities of all stars belonging to the cluster down to 9th apparent magnitude. It is at once obvious that the average observed velocity of rotation of the early-type members is very much larger than for the mean of all stars in the galaxy. This predominance is especially well shown if only the inner parts of the cluster are considered. In the table below I have included the cluster of the Hyades to show that in it the average rotations are much smaller than in the Pleiades.

Sp. Type	*Inner Pleiades*		*Hyades*		*Galaxy*	
B	173 km/sec	(7)	.....		73 km/sec	(275)
A	69	(15)	42	(18)	87	(87)
F	75	(2)	34	(28)	23	(23)

The large rotations of the Pleiades are not caused by excessively large rotations of a few stars, but by an unusually large number of stars having rotations similar to the largest encountered elsewhere in the galaxy. This tends to support our view that rotational velocity is limited by equatorial break-up.

The Pleiades are also relatively rich in emission line stars. Among the brighter stars, Electra, Merope, and Alcyone, in addition to Pleione, have emission lines of hydrogen.

The conclusion suggests itself that all B stars in the Pleiades have rapid rotations, and that the few with narrow lines happen to have their axes oriented in the line of sight. If this is true, then Maya with its narrow lines is a star whose polar regions are seen from the Earth. It is possible that this accounts for some of the spectroscopic anomalies which have been found in Maya.

10. We conclude this article by presenting one or two speculations concerning the origin of the rotational motions in stars. From the work of Trumpler it appears probable that there are several other clusters, besides the Pleiades, in which the early-type members are characterized by large rotations. This suggests that the origin of these rotations is

somehow related to the environment of the stars, and is not a product of purely internal processes.

Whether great star density in space has an important effect is doubtful. The rotations do not, apparently, depend upon the density of the cluster. It is more probable that the presence of nebulous matter in the Pleiades, and the absence of such matter in the Hyades, is relevant. Perhaps it will be necessary to make use of some of the old theories of the infall of small particles into stars, in order to account for the large rotations.

The astrophysical problems which have been opened by the study of Pleione and other similar stars are almost unlimited, and have as yet barely been touched upon. We know that the pressure in the shell of Pleione is about 1000 times less than in the reversing layer. The electron temperature is high, and may be as high as the temperature of the reversing layer. But the degree of ionization of the shell is lower.

The excitation of the atoms must be due almost wholly to the absorption of star light. Since this is weakened by the great distance of the shell from the stellar photosphere, the conditions are no longer even approximately similar to those of thermodynamic equilibrium. This may account for certain anomalies in the development of the metallic spectrum of Pleione, which run contrary to the theory of ionization as derived for equilibrium conditions. It was noticed that in the early stages of the shell's development the absorption lines of ionized nickel were abnormally strong, and those of ionized chromium and iron were fairly conspicuous, relative to a normal supergiant star like α Cygni. Gradually, other lines, especially of ionized titanium, became prominent, but until about a year ago the lines of ionized manganese remained abnormally weak. Since then these lines have also strengthened a great deal, so that at the present time the relative intensities of all these elements are similar to those observed in α Cygni. The peculiar behavior of the elements is not in accord with their ionization and excitation potentials, and all attempts to explain it have failed.

What happens to a ring after it has formed? Does it condense into planets as Laplace had once suggested? The observations prove conclusively that the rings are relatively unstable structures and that they tend to dissipate into space. In some cases, like γ Cassiopeiae and β Monocerotis, we have observed the gradual disappearance of a shell absorption spectrum. This can only mean that the gases are slowly projected outward—probably by radiation pressure—and are lost in interstellar space.

YERKES OBSERVATORY, FEBRUARY 17, 1943.

Navigation with a Watch—II

By CHARLES H. SMILEY

In the first article of this title which appeared in the March issue of POPULAR ASTRONOMY, there was given a method of determining one's geographic position, longitude, and latitude, which required only a watch. To find one's position is only half of navigation; the other half is to find which way to go. This article concerns the second problem and is intended for the man whose boat has a sail (or other motive power), a compass, and a rudder. The method presented here is not intended as a substitute for more refined methods; it is offered only for emergencies where there is a lack of instruments, tables, or trained navigators.

BASIC PRINCIPLE

The basic principle is simple and can be explained without the use of any mathematics. Suppose that one wishes to reach Recife, Brazil, from an unknown position somewhere in the Atlantic; suppose further that it is known that a particular star, Rigel, say, will be directly overhead at Recife at 8:36 P.M., Eastern War Time, on the day in question. One can determine the course to be followed by pointing the boat toward this star at 8:36 P.M., E.W.T. This course may be held by the use of the compass for 23 hours 56 minutes, at the end of which time Rigel will again be over Recife and the course may be determined for the following day. The path followed by this method will be a good approximation to a great circle, the shortest possible path to the destination.

Furthermore, the angular distance of the star from the observer's zenith at the instant the star is over the destination is equal to the distance from the observer to that destination. Multiplying the number of degrees by 60 converts the distance to nautical miles. It is obvious that the method will be useful only for zenith distances less than 90° (the star must be above the horizon to be observed) and hence only for destinations less than 5400 nautical miles away.

It is seen that the method will provide the facts which are needed if one is to make an intelligent decision as to which way one should go.

The problems to be solved are:

> Which star will pass directly over the destination?
>
> When will it be over that point?
>
> How may one, without instruments, estimate the angular distance of that star from the zenith, and thus the distance in nautical miles to the destination?

These problems will be discussed in the order given.

Zenith Stars

Which star will pass through the zenith at the destination? *The declination of the star must equal the latitude of the point beneath it, the sub-stellar point.*

To continue the example offered above, Recife, Brazil, is in latitude 8°.1 South. The star, Rigel, whose declination is —8°.3 will pass over a point 13 miles south of the port; this star would be entirely suitable as a zenith-star for Recife. So also would be Alphard, δ Librae, and μ Ophiuchi. Thus with a good star-map and a catalog of star-positions, one can list ahead of time a number of zenith-stars for a given port. At the end of this article, a number of ports are listed with some of their brighter zenith-stars.

Zenith Times

Next one considers the problem, "When will a particular star be at the zenith of a port?" Here it is assumed that the star has the proper declination so that at some time it will be at the zenith of the port. Also it may be pointed out that one may use the tables even though one does not understand the theory underlying their construction.

The star is at the zenith of the port at the moment when the Greenwich hour angle of the star equals the west longitude of the port (counted up to 360°).

But the Greenwich hour angle of the star is equal to the Greenwich hour angle of the Vernal Equinox plus the sidereal hour angle (SHA) of the star. The latter two quantities may be taken directly from the *American Air Almanac*. The sidereal hour angles of only a limited number of stars are given there; one may note that

$$\text{SHA} \bigstar = 360° - \alpha°$$

where $\alpha°$ is the right ascension of the star in degrees.

We have then, when the star is over the port,

$$\text{GHA} \bigstar = \text{West longitude of the port}$$
$$\text{GHA} \bigstar = \text{GHA} \Upsilon + \text{SHA} \bigstar$$

Therefore,

$$\text{West longitude} - \text{SHA} \bigstar = \text{GHA} \Upsilon.$$

Thus one may start by subtracting the star's sidereal hour angle from the west longitude of the port (adding 360° to the latter quantity if necessary to avoid negative quantities). This gives the required Greenwich hour angle of the Vernal Equinox; one then determines the corresponding Greenwich Civil Time for the date from the *American Air Almanac*. If the *Air Almanac* is not at hand, one may use the *Nautical Almanac* to transform the Greenwich hour angle of the Vernal Equinox (which is equal to the Greenwich sidereal time) to the corresponding Greenwich Civil Time for the date.

One notes, however, that all of this work can be taken care of ahead

of time. As remarked previously, the user need not be bothered to learn how the values given in the tables were derived. At the end of this article is given a list of 14 ports in the North Atlantic Ocean and 20 in the Pacific Ocean. For each of these are given three or four zenith-stars and the zenith-time in Greenwich Civil Time for each star for January 1, 1943. There is also a simple auxiliary table, for use with all stars and all ports, which tells how much to subtract from the zenith-time of January 1, 1943, to obtain the zenith-time for any other day up to January 1, 1951. It would be easy to extend the table beyond that point.

With the formulas given above, the reader may assemble data for ports around any ocean in which he is likely to travel. The material might easily be printed on the back of a star map similar to the one in the *American Nautical Almanac* (but perhaps with more stars shown). The star maps appearing in "Astronomy" by John C. Duncan (Harper and Bros., New York) are available as a separate leaflet and are satisfactory for use with this method. It should be pointed out that not all stars appearing in the tables are shown on these maps. It may be emphasized that to use this method one must have a watch which will keep good time, a compass to hold the course, a good star map, and data similar to those at the end of this article.

Distance to Destination

The questions, "How far is it to this port? To that one?", are important in that their answers enable the man in the life-boat to decide which port to steer for. It has been indicated that the zenith distance of a star measures the distance from the observer to the sub-stellar point (in this case, a port considered as a possible destination). Without an instrument of any sort, how can one estimate the zenith-distance? It will be easiest to estimate the altitude of the star (since it is measured from a visible line, the horizon) and to obtain the zenith-distance by subtracting the altitude from 90°. If one knows the angular separation of a pair of bright stars, one can use this as a unit and, with a stick or pencil held at arm's length and approximately perpendicular to the line of sight, measure the desired altitude. The angular separations of ten pairs of stars scattered over the sky are given in the tables at the end of the article.

Course on Approaching the Destination

If one is approaching a port such as Rio de Janeiro from the east, one is not worried about missing South America, but with Bermuda or Midway Island it is a different story. As the days pass and the zenith-star of the destination appears nearer and nearer to the traveller's zenith at zenith-time, it becomes more and more difficult to estimate the direction in which one should move. In fact, it may appear that the star passes directly overhead at the proper time and still the traveller has not

reached his destination. In such a case, the difficulty is probably due to an error of the watch being used, and a resulting error in longitude. The boat then may be run due east or due west, as seems wisest, looking for the island.

Limitations

Obviously this method may be used on the land, at sea, or in the air. For the reasons given above, it is useful only for destinations less than 5,400 nautical miles away. Since the course should be changed every few hundred miles if the path is to approximate a great circle, the method would lose some of its efficiency when used with a fast-moving vehicle, say of speed 50 miles per hour or greater. It is clear that slight modifications are required when the method is used aboard a fast motor torpedo boat or a plane.

Use of the Tables

To find the initial course to a particular port listed in the tables.

1. Add the time-intervals opposite the year, month, and the day in the auxiliary tables. For example, for 1944, February 19, add the quantities opposite 1944, February, and 19. [$-1^m0 + 2^h1^m9 + 1^h10^m8 = 3^h11^m7$]. In a Leap Year, count February 29 as March 1, March 1 as March 2, *etc.*, to the end of the year in entering the tables.
2. Subtract this sum from the zenith-time for each star listed for the port, adding 23 hours 56 minutes if necessary to the latter to obtain a positive result. This will be the Greenwich Civil Time at which the star will be directly over the port. It should be noted that on *one* day each year, a given zenith-star will come to the zenith *twice* between midnight and midnight; the first time less than four minutes after midnight and the second time less than four minutes before midnight. The auxiliary table is designed to give one zenith-time per day; in the special case where there are two, the second is 23 hours 56 minutes after the one given by the table. It may be pointed out that zenith-times for January 1, 1943, and auxiliary intervals are given to tenths of minutes in the hope that the calculated zenith times for particular days will be in error by less than a minute.
3. If the watch is not set to Greenwich Civil Time, the computed time must be transformed to watch time. Subtract four hours from Greenwich Civil Time to obtain Eastern War Time, seven hours to obtain Pacific War Time. In any case, one must allow for the amount the watch is fast or slow.
4. At the computed time, observe the direction of the star. This direction may be used as a course for 23 hours 56 minutes by any vessel whose speed is 20 knots, say, or less. At the end of that time, the star will again be over the port and the course is determined anew.

To determine the distance to the port.

1. Using the known angular distance between a pair of bright stars as a unit [Ten such distances are given at the end of this article.], estimate the altitude (angular elevation above the horizon) of the zenith-star at

the computed zenith-time. The zenith-distance is then 90° minus the observed altitude.

2. Multiply the number of degrees in the zenith distance by 60 to obtain the distance in nautical miles.

Example

July 4, 1943, desired destination Boston. To find the zenith-stars and zenith-times.

0 mins. + 11 hrs. 51.6 mins. + 0 hrs. 11.8 mins. = $12^h\,03^m4$

For

γ Andromedae	$24^h\,00^m7 - 12^h\,03^m4 = 11^h\,57^m3$ G.C.T.
μ Ursae Majoris	$32^h\,17^m9 - 12^h\,03^m4 = 20^h\,14^m5$ G.C.T.
σ Herculis	$14^h\,34^m2 - 12^h\,03^m4 = 2^h\,30^m8$ G.C.T.

For a person on the Atlantic, the third star would be best because it would be seen all night long.

Concluding Remarks

This method, in general principle, is similar to that used by the Micronesians in their navigation of the Pacific as described by James Hornell in his book, "Canoes of Oceania." They did not have watches to measure time; they had to rely on other information to make up for this lack.

The fundamental idea that the Greenwich hour angle and declination of a star at the observer's zenith are equal, respectively, to his west longitude and latitude, may be used to determine, more or less accurately, one's position. It would be easier to use this principle if the *American Nautical Almanac* tabulated the Greenwich hour angle of the Vernal Equinox for the beginning of each day, perhaps instead of one of the navigation stars, say Ruchbah. Also it would help if the mean Sidereal Hour Angle and declination were given for each of 250 additional bright stars identified on the star map. In this connection, it may be mentioned that the star labelled γ Scorpii on the *Nautical Almanac* star map is listed as σ Librae in modern standard catalogues; this is simply a case where a name was changed about eight years ago and the corresponding change was not made on the map.

Data in the *Yale Catalogue of Bright Stars* were used in the preparation of the tables; the *A.A.V.S.O. Star Atlas* was used in selecting the zenith-stars. The author wishes to acknowledge his indebtedness to Professor Alice H. Farnsworth of Mt. Holyoke College who has kindly read this article and offered many valuable constructive criticisms.

Angular Separations of Pairs of Bright Stars

Ursa Major	α to β	5°.4	Canis Major	δ to η	4°.5
Cassiopeia	α to β	5.1	Grus	α to β	5.9
Cygnus	α to γ	6.1	Crux	α to γ	6.0
Gemini	α to β	4.5	Crux	β to δ	4.3
Bootes	α to η	5.1	Centaurus	α to β	4.5

TABLE FOR CONVERSION OF ZENITH-TIME ON JANUARY 1, 1943, TO DATE

Years	m	Months	h m	Days	h m	Days	h m
1943	0.0	January	0 00.0	1	0 00.0	17	1 02.9
1944	−1.0	February	2 01.9	2	0 03.9	18	1 06.8
1945	+2.0	March	3 51.9	3	0 07.9	19	1 10.8
1946	+1.0	April	5 53.8	4	0 11.8	20	1 14.7
1947	+0.2	May	7 51.8	5	0 15.7	21	1 18.6
1948	−0.8	June	9 53.6	6	0 19.7	22	1 22.6
1949	+2.2	July	11 51.6	7	0 23.6	23	1 26.5
1950	+1.2	August	13 53.5	8	0 27.5	24	1 30.4
		September	15 55.4	9	0 31.5	25	1 34.4
		October	17 57.3	10	0 35.4	26	1 38.3
		November	19 59.1	11	0 39.3	27	1 42.2
		December	21 57.1	12	0 43.3	28	1 46.2
				13	0 47.2	29	1 50.1
				14	0 51.1	30	1 54.0
				15	0 55.0	31	1 58.0
				16	0 59.0		

ZENITH-STARS FOR FOURTEEN PORTS IN THE NORTH ATLANTIC WITH ZENITH-TIMES FOR JANUARY 1, 1943

ST. JOHNS, NEWFOUNDLAND	h m
δ Persei	0 30.4
κ Ursae Majoris	5 50.4
o^3 Cygni	17 02.5

NASSAU, BAHAMAS	h m
ε Geminorum	5 10.0
δ Herculis	15 40.6
κ Pegasi	20 09.2

BOSTON, MASS.	h m
γ Andromedae	0 04.7
μ Ursae Majoris	8 21.9
σ Herculis	14 34.2

PUERTO RICO	h m
ε Tauri	2 08.4
η Boötis	11 33.5
δ Sagittae	17 25.4
γ Arietis	23 30.0

CAYENNE, GUIANA	h m
ν Tauri	0 50.2
α Canis Minoris	4 25.8
β Ophiuchi	14 28.5
ν Pegasi	18 49.9

DAKAR, WEST AFRICA	h m
β Leonis	6 15.8
δ Delphini	15 08.9
α Pegasi	17 29.7
γ Tauri	22 43.4

GALWAY, IRELAND	h m
κ Cygni	13 12.6
ζ Cassiopeiae	18 29.7
γ Persei	20 56.2

MADEIRA IS.	h m
α Geminorum	1 58.2
ξ Ursae Majoris	5 41.7
γ Lyrae	13 22.1

ST. PAUL ROCKS	h m
55 Leonis	6 10.2
68 Ophiuchi	13 15.0
η Aquilae	15 05.5
π Aquarii	17 37.9

RECIFE, BRAZIL	h m
β Orionis	0 52.0
α Hydrae	5 4.3
δ Librae	10 36.6
μ Ophiuchi	13 13.0

LISBON, PORTUGAL	h m
α Canum Venaticorum	6 50.4
γ Boötis	8 26.6
α Lyrae	12 31.1
ν Aurigae	23 41.9

AZORES	h m
ν Aurigae	0 57.5
α Canum Venaticorum	8 02.1
γ Boötis	9 38.3
α Lyrae	13 42.8

CAPE VERDE IS.	h m
γ Geminorum	1 35.2
v Boötis	8 46.2
κ Herculis	11 4.6

BERMUDA	h m
α Geminorum	5 10.6
ζ Ursae Majoris	8 53.6
γ Lyrae	16 34.1

ZENITH-STARS FOR TWENTY PORTS IN THE PACIFIC OCEAN WITH ZENITH-TIMES FOR JANUARY 1, 1943

GALAPAGOS Is.	h	m
δ Orionis	4	51.2
γ Virginis	11	59.7
α Aquarii	21	22.3

CLIPPERTON Is.	h	m
o Leonis	10	14.2
ι Ophiuchi	17	26.3
γ Aquilae	20	18.0

SAN FRANCISCO, CALIF.	h	m
θ Aurigae	7	24.4
β Leonis Minoris	11	52.4
ζ Lyrae	20	09.3
τ Cygni	22	38.6

MARQUESAS Is.	h	m
o Leonis	12	14.3
ι Ophiuchi	19	26.4
γ Aquilae	22	18.2

HONOLULU, HAWAII	h	m
ζ Tauri	9	25.1
δ Leonis	15	01.0
112 Herculis	22	38.5

MANZANILLO, MEXICO	h	m
ε Tauri	4	42.8
η Boötis	14	07.9
γ Herculis	16	34.9
γ Sagittae	20	11.2

EASTER ISLAND	h	m
γ Pyxidis	9	25.2
χ Hydrae	11	39.3
φ Sagittarii	19	17.5
ε Piscis Austrini	23	12.3

SEATTLE, WASHINGTON	h	m
δ Persei	5	08.3
κ Ursae Majoris	10	28.3
o^2 Cygni	21	40.4

SOCIETY Is.	h	m
θ Capricorni	0	21.6
α Leporis	8	47.6
α Crateris	14	13.6

PALMYRA Is.	h	m
β Aquilae	0	01.8
ν Tauri	8	08.1
γ Orionis	9	29.8
α Canis Minoris	11	43.7

DUTCH HARBOR, ALASKA	h	m
δ Aurigae	10	20.1
γ Ursae Majoris	16	15.2
κ Cygni	23	38.9

FIJI Is.	h	m
θ Capricorni	2	29.3
α Leporis	10	55.3
α Crateris	16	21.3

WAKE ISLAND	h	m
γ Sagittae	2	10.5
ε Tauri	10	38.1
η Boötis	20	03.3
γ Herculis	22	30.3

SYDNEY, AUSTRALIA	h	m
ε Sagittarii	1	36.2
η Sculptoris	7	40.0
α Columbae	12	51.6
β Hydrae	19	03.0

TOKYO, JAPAN	h	m
β Andromedae	9	07.2
ξ Persei	11	55.5
α Lyncis	17	17.0
κ Coronae Borealis	23	47.4

MIDWAY Is.	h	m
β Cygni	0	38.7
α Andromedae	5	15.0
β Geminorum	12	50.2
β Comae Berenices	18	16.6

WELLINGTON, N. Z.	h	m
θ^1 Microscopii	2	58.4
φ Gruis	4	56.0
q Velorum	15	51.5
ν Centauri	19	24.7

SOLOMON Is.	h	m
τ Ophiuchi	0	51.6
ξ Aquarii	4	25.8
β Orionis	12	01.6
α Hydrae	16	13.9

GUAM	h	m
ζ Aquilae	2	44.8
o^2 Orionis	12	33.6
ξ Geminorum	14	22.2
χ Serpentis	23	17.7

MANILA, P. I.	h	m
α Pegasi	8	17.5
ρ Tauri	13	45.3
ψ Leonis	18	54.4
ζ Boötis	23	51.4

LADD OBSERVATORY, BROWN UNIVERSITY, PROVIDENCE RHODE ISLAND, MARCH 1, 1943.

Observations of Brightness of Comets 1941d and 1942a

By ALICE H. FARNSWORTH

It may be stimulating to others to go and do (not likewise but) better, to place on record two short series of observations which represent first attempts at a type of photometric estimate which would seem to be beset with considerable uncertainty. Except where otherwise noted the observations were made with a visual refractor (aperture 8, focal length 110 inches) equipped with a large-field eyepiece of magnifying power 50. The eyepiece was racked in (usually ¾ of a revolution of the focusing screw) until the comparison stars showed as luminous disks of approximately the area of the cometary image.

In Table 1, H indicates the total brightness of the comet deduced from B.D. magnitudes of comparison stars listed in Table 2. Values in parentheses are based on the Harvard photovisual system. In only a few cases were these determinations possible. The record of each comparison places the brighter object first.

TABLE 1

OBSERVATIONS

COMET 1941 *d* (VAN GENT)

No.	U.T. 1941	Comparison	H	Remarks
1	Sept. 17.03	a 8 H 2 d	7^m4	Obs'n by J. R. Gill
		c 3 H 1 d	7.7	Sky pretty thick
2	Sept. 19.01	H = f	8.0	Aurora!
3	Sept. 20.01	f 1 H 4 g	8.2	Estimate uncertain; f colored
4	Sept. 22.01	f 3 H 7 h	8.2	Obs'n by J. R. Gill
		H 1 f	7.8	Unsteady. Step-value as in No. 3
5	Sept. 23.01	j 2 H 2 k	7.6 (7.5)	
6	Sept. 25.01	k 6 H 4 l	7.6 (7.6)	Obs'n by J. R. Gill
7	Sept. 27.00	H = m	8.3 (7.8)	Moon
		s 3 H 1 n	7.6	Comet probably in tree-tops
8	Sept. 27.99	H = m	8.3 (7.8)	Hurried, uncertain, sky bright

COMET 1942 *a* (WHIPPLE)

No.	U.T. 1942	Comparison	H	Remarks
1	Feb. 10.27	c 2 H 2 a	8^m6	Diffuse halo with brighter center
2	Feb. 13.15	d 2 H 3 e	7.5	Focused in 1 rev.
3	Feb. 15.15	f 1 H 3 g	8.2	Drifting clouds. 1/2 rev.
4	Feb. 16.15	h 2 H 2 j	7.6	1 rev. Conditions good
		h 2 H 1 j	7.8	3/4 rev.
5	Feb. 20.11	H > k, slightly	7.8 (7.6)	Conditions good
		1 3 H 1 k	7.8 (7.5)	In 2-inch finder
6	Feb. 22.14	H = or < m	8.1 or 2	Sky clouding
		p 3 H 1 m	7.7	
7	Mar. 8.06	H > a, b, c	8.2	Thick and poor
8	Mar. 13.06	t 2 H 2 w	8.6	Clouds kept coming
9	Mar. 20.02	x 2 H 1 z	...	Recently cleared, unsteady
		x 2 H 2 y	7.8	Obs'n by M. R. Hunt

In Table 2, the B.D. number (distinguished by zone-prefix) replaces

the number given in the *Henry Draper Catalogue* in several cases. Magnitudes on the Harvard photovisual scale[1] are recorded where possible.

TABLE 2

COMPARISON STARS

1941 *d*					1942 *a*					1942 *a*				
	HD or		Mag.			HD or		Mag.			HD or		Mag.	
*	BD No.	Sp	BD	HP_v	*	BD No.	Sp	BD	HP_v	*	BD No.	Sp	BD	HP_v
a	104513	A3	5.1	5.04	a	+20°2720	...	9.3	....	p	100180	G0	6.4	6.63
c	104556	K0	6.7	6.47	c	108652	F0	8.0	....	q	87035	A5	8.4	....
d	104178	K0	8.0	....	d	106972	F5	7.0	7.46	r	87649	F8	8.8	....
f	102857	G5	8.0	....	e	+19°2550	...	8.3	....	s	87623	G5	8.3	....
g	+44°2133	...	8.9	....	f	105260	A5	8.0	....	t	87072	F5	7.8	....
h	+44°2126	...	8.5	....	g	+18°2569	...	8.8	....		73	A3		
j	101967	F5	7.3	7.69	h	104999	F2	7.0	7.58	w	−2°2903	...	9.4	....
k	101585	Ma	7.8	7.28	j	104923	G5	8.2	....	x	74915	K0	7.5	7.35
l	101549	A2	7.5	7.88	k	102343	A5	8.0	7.83	y	74833	K2	8.0	....
m	101227	G0	8.3	7.79	l	102103	K0	7.4	6.47	z	.....	...	...	....
n	101300	G5	8.0	....	m	100486	K2	8.1	....					
s	100972	B9	6.5	6.63										

In the case of the first comet, compromise had always to be made between waiting for the northwest to become really dark, and letting the comet get so low that it would be lost in the tops of the trees northwest of the observatory. Work on the second was terminated by the advent of spring vacation.

It is tempting to make a comparison between these somewhat fragmentary values and the results published by Bobrovnikoff[2] on dates common to both series.

		B − F (M)			B − F (M)
1941d	Sept. 17	−0.2	1942a	Mar. 8	−1.8
	Sept. 22	−0.4		Mar. 13	−2.2
	Sept. 23	−0.2		Mar. 20	−1.5
	Mean	−0.3		Mean	−1.8
		General mean	−1.0		

The amount by which the 8-inch telescope records the comet fainter than do the binoculars (aperture 1.1 inches) is fairly consistent for each comet, but widely different for the two comets. The general mean is almost exactly the difference (−1ᴹ.1) to be read from the curve in Bobrovnikoff's treatise[3] on the brightness of comets, where systematic corrections to H dependent on aperture are exhibited, as derived from extensive material.

[1] Taken from *Harvard Observatory Mimeograms*, Series III, 1938.
[2] POPULAR ASTRONOMY, Vol. L, p. 306, 1942.
[3] *Contributions from the Perkins Observatory*, No. 15, p. 63, 1941.

Uncommon Easter Dates

By ALEXANDER POGO

The problem of finding the first Sunday *following* the fourteenth moon (*luna XIV* of the Easter lunation, the cyclical Easter new moon being the first day of that lunation) *falling on or following* March 21 (the stabilized date of the vernal equinox), involves three cycles: the tropical year, the lunations, and the week. If we know the date of the first cyclical new moon of the year (or the age of the cyclical moon on January 1) and the date of the first Sunday of the year, we can find the March and April dates of the cyclical new moons and of the Sundays. Since both lunations and dates of the year are involved, the Metonic cycle of 235 lunations or 19 years plays an important part in the history of Easter tables.

On p. xvii of the *American Ephemeris and Nautical Almanac* for the year 1943, we find the following data for the current year of the Gregorian calendar: Golden Number, 6; Epact, XXIV; Dominical Letter, C.

The Golden Number, now obsolete, gives the position of a given year in the 19-year lunar cycle. The Golden Number 1 corresponds to A.D. 19, to A.D. 38, . . . to A.D. 1938, a multiple of 19; the Golden Number was, therefore, 3 in 1940, and it is 6 in 1943.

The Epact shows the age of the cyclical moon on January 1 of the year and it marks the dates of the cyclical new moons of the year. Between A.D. 1900 and A.D. 2199, Epact XXIV corresponds to Golden Number 6; either the Golden Number or the Epact may be used in constructing Easter tables.

The Dominical Letter—C in 1943—means that the first Sunday of the year fell on January 3 (the count begins with A on January 1); we do not need a calendar in order to find that January 10, February 14, March 14, and April 18 are C-days or Sundays in 1943.

Table I gives the cyclical new moons and full moons of the first four months of 1943. It shows that, in March, *luna XIV* falls on a date preceding the stabilized vernal equinox date; the cyclical Easter new moon is, therefore, April 5, and the *luna XIV* of the Easter lunation falls on April 18. Now, the Dominical Letter of April 18 is C; the cyclical Easter full moon falls on a Sunday; Easter falls, therefore, on the following Sunday, April 25.

TABLE I

CYCLICAL NEW MOONS AND FULL MOONS, 1943

Cyclical new moons			*Luna XIV*	
Jan. 7	G	XXIV	Jan. 20	F
Feb. 5	A	XXIV	Feb. 18	G
Mar. 7	C	XXIV	Mar. 20	B
Apr. 5	D	XXIV	Apr. 18	C

Easter tables give, of course, the date of Easter Sunday directly, when the Dominical Letter and either the Golden Number or the Epact is known. The above step-by-step determination of the Easter date of 1943 ought to show that very late Easter dates imply both an Epact which makes the March cyclical new moon fall short of the conventional vernal equinox date and a Dominical Letter which makes the *luna XIV* of the Easter lunation fall on a Sunday. Similarly, very early Easter dates imply both an age of the cyclical moon on January 1 which makes the March cyclical full moon fall on March 21 or a day or two later, and the Dominical Letter which makes the *luna XIV* fall on one of the week-end days preceding Sunday. Thus, in 1940, the Epact was XXI and the Dominical Letter was GF (leap year); the cyclical Easter new moon fell on March 10, the *luna XIV* of the Easter lunation fell on March 23, a Saturday, and Easter Sunday was, therefore, March 24, an exceptionally rare Easter date in the Gregorian calendar.

TABLE II

EARLY AND LATE GREGORIAN EASTER DATES

March 22	March 23	March 24	April 23	April 24	April 25
1598					
1693	1636		1628	1639	1666
	1704			1707	1734
1761	1788	1799		1791	
1818	1845		1848	1859	
	1856				1886
	1913		*1905*		
		1940	1916		1943
	2008		*2000*	2011	2038
			2079	2095	
	2160		*2152*	2163	2190
2285	2228		*2220*	2231	2258
2353	2380	2391		2383	2326

The Gregorian Easter dates of Table II cover more than eight centuries, from the Gregorian calendar reform (1582) to the year 2399. A similar table, not reproduced here, was compiled for Julian Easter dates, covering the same period. A comparison of the frequency of the Easter dates in both tables is given in Table III, along with the maximum intervals; March 24 is the most unusual Gregorian Easter date, and the interval of 467 years between March 22, 1818, and March 22, 2285, holds the record for "absenteeism."

TABLE III

FREQUENCY AND INTERVALS

Easter Sundays	Frequency (A.D. 1583 to A.D. 2399) Gregorian	Julian	Maximum Intervals Gregorian	Julian
March 22	6	5	467 years	247 years
March 23	10	12	152	163
March 24	3	13	451	163
April 23	8	13	220	163
April 24	9	14	152	163
April 25	8	6	152	247

In 1942, the Julian Easter Sunday fell on March 23; the equivalent Gregorian date was April 5, the Gregorian Easter Sunday of last year. In 1943, the Julian Easter Sunday falls on April 12; the equivalent Gregorian date is April 25, the Gregorian Easter Sunday. In the XXth century, Gregorian and Julian Easter Sundays coincide 26 times, although their respective dates are separated by 13 days, as in the two examples just given; in 48 cases Gregorian Easter Sunday precedes Julian Easter Sunday by one week; in 21 cases, by five weeks; and in 5 cases, by four weeks. Calendar reformers who object, for commercial reasons, to late Gregorian Easter dates ought to keep in mind that the Gregorian calendar reform stabilized the date of the vernal equinox and introduced refinements in the Easter computations which cause 74 Gregorian Easter Sundays of the XXth century to precede the corresponding Julian Easter Sundays by at least one week; they ought to think of the Gregorian May dates equivalent to the Julian Easter dates falling on April 18 to April 25.

The Gregorian Easter dates listed in the first three columns of Table II are equivalent to early March dates in the Julian calendar; a coincidence of Gregorian and Julian Easter Sundays is, therefore, excluded. The Gregorian Easter Sundays listed in the last three columns of Table II coincide, as a rule, with Julian Easter Sundays; the four italicized years are exceptions to this rule; see Table IV.

The Julian Easter Sundays falling on late April dates cannot, of course, coincide with the corresponding Gregorian Easter Sundays. The Julian Easter Sundays falling on March 22, March 23, and March 24, coincide, as a rule, with Gregorian Easter Sundays; the three exceptions, the March 24 Julian Easter Sundays of 2143, 2238, and 2333, are listed in Table IV.

TABLE IV

MARCH 24 (JULIAN) AND APRIL 23 (GREGORIAN)

Year	Julian Easter Sunday	Equivalent Gregorian Date	Gregorian Easter Sunday
2143	March 24	April 7	March 31
2238	March 24	April 8	April 1
2333	March 24	April 9	April 2
1905	April 17	April 30	April 23
2000	April 17	April 30	April 23
2152	April 16	April 30	April 23
2220	April 15	April 30	April 23

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Reminiscences

By TILTON C. H. BOUTON

Knowing that the writer of the following article has maintained an active interest in the subject of astronomy for many years, that he has made numerous, valuable reports to the A.A.V.S.O. of the results of his observations of variable stars, and that he has been a subscriber to POPULAR ASTRONOMY *from the beginning, as well as to its predecessors,* ASTRONOMY AND ASTROPHYSICS *and the* SIDEREAL MESSENGER, *we were sure that his reminiscences would be of interest to all who have in any way followed the development of astronomy in America.*

At our request, he prepared the following paper which we are pleased to share with our readers.—EDITOR.

The stars were beginning to appear, and it was bedtime for a very little boy who probably had rather continue at play than to be prepared for his crib. The girl who was with him, a dozen years older than himself, points to a bright object low in the western sky. "See that star!" she said. "It's Venus. It's most her bedtime. Now, *she is feeding her pigs, and when they have eaten their supper she will go to bed.*"

This absurd statement, probably born at the moment in the girl's imagination, was like a match to a firecracker; a spark of interest was kindled in the child mind, followed by an explosion of questions: "Who was Venus? Did she really have pigs? Had she chickens and cows and sheep? Where did she go to bed?"

How the girl answered these and other child questions, or how much she enlarged upon her original fantasy is not remembered; but she had aroused an interest in celestial objects which the boy never lost. Later, she would take him in the early evening where they could watch the sky, to see "the stars come out." Again question followed question.

That small boy was the writer; and for more than eighty years since then he has continued to question, thankful to have lived in a period of unparalleled scientific progress which has enabled astronomers of the present to answer positively some questions about which those of the past could only theorize.

As one reads Olcott's "Star Lore of All Ages" he may wonder if one, or perhaps more, among that interesting and quite complete collection of myths, may not have had its origin when some dreamer in the far misty past, sitting beneath the star-lit sky, wove his fantasies into a story for a child.

Three or four years after my queer introduction to Venus, another summons to look skyward made an unforgettable impression upon me.

My maternal grandparents were physicians, my grandmother being

the first woman to graduate from a medical college in New England. Often their practice took them together into the night hours. One cold night they reached home about midnight, and hurriedly aroused the others of the family. My grandmother shook me awake and rushed me into a room where others were excitedly watching from the windows. Stars seemed to be darting everywhere. Hardly an instant when one or more did not flash into view. With one exception, they averaged in magnitude those which are ordinarily noticed. But there was one, as bright, I think, as we ever see Jupiter, which burst into view well above the eastern horizon and seemed coming almost at us. A barn was near the house, and one of the watchers exclaimed: "It will hit the barn!" It sailed over, and the barn shut it from view. Whether it ended in an explosion, or came to Earth intact, hundreds of miles farther on, there is no way of knowing.

All I knew about this remarkable display at the time was that they were "shooting stars." I doubt if any of the observers knew what they really were.

For many years I have been trying to learn if the display was witnessed elsewhere. I feel quite confident that I saw a very unusually fine Leonid shower. It was not that of November 13, 1867, as before that date we had moved into another house. I believe it was either in 1864 or 1865, but I have been unable to find any record of unusual display in those years.

During early boyhood I learned very few astronomical facts, but acquired a large stock of superstitions, especially those connected with the Moon. *Leavitt's Farmers' Almanac* and *Ayer's Almanac* were always in the home. The former was consulted almost daily, especially by workers on the farm. Much confidence was placed in its weather predictions, and it was deemed important to keep track of the Moon's changes, if farming was to be successful. Many things must be planted during the increase of the Moon, for, if planted on the wane, the harvest would be poor. Even the butchering must be done before full Moon; if it was done during the wane, the meat when salted down would shrink in the barrel. Two superstitions were impressed upon me: the first glimpse of the new Moon must be had over the left shoulder, if one would have a month of good luck; and one must never sleep where the Moon's light could fall upon him, lest he become a lunatic.

We marvel at the superstitions held by people of seventy or a hundred years ago, but it is far more astonishing that in this astronomically enlightened day multitudes of otherwise sensible men and women believe the absolutely baseless claims of astrologers, and rely upon them to direct in all their affairs.

The principal of the academy which I was attending in 1872 was to leave at the end of the spring term. A group of his admiring scholars raised twelve dollars for purchasing a present for him. A fellow student

and myself were appointed a committee to select and purchase it. We went to a jeweler who had earned a reputation for strictest honesty, told him our mission and the amount of money we had. After showing us some jewelry and other articles, he took a spyglass from a case. I had long wished I might get a glimpse of the Moon through a telescope, but had no opportunity. Instantly it flashed into my mind that it lay there before me. The present would be in my hands two or three days before presentation, and, if the spyglass were selected my wish could be realized. Without stating my deciding motive, I urged the beauty of the instrument and its usefulness to the principal, until I persuaded my companion. The purchase was made. The Moon was past first quarter, and on two evenings the views I obtained so impressed me that I determined someday to own a telescope; but that day was ten years in the future. Then a friend gave me a 1¼-inch spyglass, which showed what I had seen on the Moon, the moons of Jupiter, and stars impossible for the unaided eye. From this meager start a series followed, culminating in the 7-inch I still use.

The class of 1878, in Dartmouth College, was privileged to have as instructor, in both physics and astronomy, Professor Charles A. Young. He had already gained wide renown for his discovery of the "reversing layer" and for other pioneer work upon the Sun. He was an ideal teacher, impressing upon his students, not only the beauty and value of the subjects, but his own fine personality. Especially in astronomy his enthusiasm was contagious, and could not fail to kindle interest in the dullest scholar. Both in and out of the classroom he was the perfect gentleman. There seemed to be always a smile upon his face, and often a sparkling of the eyes. He would look so kindly upon a student who failed in recitation (from experience I can testify to this), that no sting of failure was felt, but a determination to do better.

None who ever studied under Professor Young could wonder that the class of college girls to whom he gave a course of lectures, soon after leaving Dartmouth, bestowed upon him the sobriquet, "Twinkles," which henceforth clung to him; it was particularly appropriate to him, both as an astronomer and a man.

The larger part of Professor Young's work upon the Sun was done with the 9.4-inch Clark telescope in the observatory at Hanover. One day he told our class the history of the objective, which he believed to be probably the most perfectly corrected of any then in use. He received a summons from Alvan Clark to come to Cambridge to test it. He gave it every test of which he knew, and he pronounced it perfectly satisfactory. Clark, however, would not let it go, but put in two more full weeks of work in making final corrections before he declared it as perfect as could be made.

About thirty years after graduation, I was talking with Mr. Carl Lundin, then head of the Clark corporation, and I chanced to mention

this telescope. Great was my surprise when Mr. Lundin said that he had very recently repolished and corrected this objective. I told him what Professor Young had told us. Lundin said he corrected several errors which it was impossible for Alvan Clark to detect, and he showed me an instrument so sensitive, that when a lens was placed above it, the artificial star formed below became a flare if a hand were held for a few second just above the lens. I wonder if comparable progress has been made since that interview, towards perfecting telescope objectives.

For three years following college, theological and kindred studies required my full attention. Not until after settlement in my first parish was my interest in astronomy renewed. One of the two astronomical books I then possessed was Dick's Works. Starting to read his astronomical writings, I became fascinated, not only with the facts which he presented, but especially with his reasonings and imaginings. He could vision every planet with beings more developed and perfect than ourselves, even putting them on the rings of Saturn and on wandering comets. His writings again quickened me to astronomical study, and led to a line of experimenting which culminated in lens-making and to an increase in telescopic equipment. I did not wonder when, years later, I read that the reading of a copy of Dick's "Practical Astronomer," left for a short time in the studio where he was employed, started Professor E. E. Barnard upon his distinguished career.

For more than twenty years my telescopes were used for my own observing and for interesting and instructing individuals and groups who would come to look through them. From the start, I found much pleasure in welcoming people who would like a glimpse of celestial objects, and there has been no break in this custom to the present time. In large observatories the work is so important that, with rare exceptions, the telescopes must be employed continuously along professional lines. The amateur is not under restraint, and the possessor of a telescope of moderate size can do much good by sharing in its use, and I think there is quite an obligation upon him to do so.

It had not occurred to me before 1911 that I could undertake any work of direct value to astronomy, but Wm. Tyler Olcott wrote me, setting forth the need of work upon variable stars, and urging me to be one of a little group who were beginning to observe. This communication from Mr. Olcott opened the way to an acquaintance with one of the finest persons I have ever known and to a highly prized and helpful friendship.

Mr. Olcott's attainments as a scholar and author, his untiring zeal in promoting and serving the A.A.V.S.O., and the honors he received at home and abroad are too well known to need mention in this paper. Only those who came into personal touch with him could appreciate the charm of his personality. His love for rendering service and finding his reward only in the joy of serving was characteristic, and it must

at times have brought a glad surprise to some who received his aid. Help which he once gave me revealed that spirit, and I believe the act was far from exceptional.

I used for several years a 5-inch telescope of excellent quality which I was unable to sell to prospective buyers, because an almost indetectable scratch across the face of the flint lens had not been worked off by the makers. I wrote them of the trouble, and they directed me to send the objective to them, and they promised to refinish it. For two years they held it without doing a stroke of correcting work. My repeated urgings only brought back excuses. In a letter to Mr. Olcott I mentioned this. He immediately offered me his services as a lawyer, if I would give him authority to act, which I gladly did. The result was the return of the objective in a short time, perfectly refinished. For this legal service Mr. Olcott would accept no pay. The telescope was so satisfactory that he purchased it and installed it in his unique house-top observatory, at Norwich, Connecticut. In my library, "Sun Lore of All Ages" and "Star Lore of All Ages"—gifts to me by him—help me to hold him in grateful memory.

Near the close of his last winter in Miami, where he had devoted a good part of his time and effort in renewing the Observatory of the Southern Cross, he and Mrs. Olcott came to St. Petersburg for a brief stop before returning home. We had planned for several evenings together at the telescope, but he could come only once. He was suddenly stricken with a serious illness, which I think was largely due to overtaxing of strength in his unselfish work while in Miami, and which I fear hastened his lamented death.

The earlier members of the A.A.V.S.O. had not only Mr. Olcott as their helper and inspirer, but they found in Professor E. C. Pickering an equally interested and helpful friend. He was not only the father of the association in that he started Mr. Olcott on his organizing work, but he showed a fatherly attitude towards those who were beginning to observe. This was experienced by me. The charts sent to the earlier observers were crude, compared with those now furnished. The first sent to me represented the fields on a scale so small that there was much difficulty in their use; so I undertook to make enlarged copies. A little later better charts were received; but, because of scarcity, I copied them, returning the Harvard charts. I also experimented in making charts on which the stars were represented by holes punched through cardboard, each hole given a diameter according to the magnitude of the star. Such charts were to be used in a lantern designed to throw light through the holes representing the stars. The first copied charts I sent to Professor Pickering. He was always ready to examine any experiment and to approve or disapprove, as the case might need. Some of my first estimates were poor, and he kindly indicated the probable causes and how to avoid them.

All who were privileged to attend at Harvard Observatory the early gatherings of the association must have felt Professor Pickering's fatherly spirit. He seemed as glad as a father who welcomes his returning sons and daughters to a family banquet. At one of these meetings he modestly told of an incident which revealed his intense devotion to his profession. When in his vast work in determining the brightness of many thousands of stars with the meridian photometer which he devised, he had reached the one millionth setting with it, it was told him that he ought to celebrate the event by taking an evening off, and attending the theatre, which I understand he had never done. At first he viewed the proposition with favor. A ticket was purchased and a seat reserved. But as it drew towards evening, he began to hesitate. Attendance at the theatre would be pleasant, if he could keep his mind, as well as his body, present. The work he was following was important, and there was pleasure also in it. His work won over the theatre; he gave the ticket to a friend, and again sat down at the telescope.

After becoming a resident of St. Petersburg I never again met Professor Pickering. But nearly three months before his death a letter from him awakened happy anticipation. He wrote that he and Professor Bailey were planning to spend the winter, in whole or part, with one or two others, in St. Petersburg; and he asked me to give him data regarding cottages and apartments, as they expected to keep house while here. I was delighted to meet his request, as their coming would mean so much to me in the renewal of acquaintance. Great was my disappointment when I received word that their plan was abandoned. I have felt that, had the plan been carried out, Professor Pickering would have escaped the illness which was fatal.

When I became a citizen of Florida I feared that, being unable to attend future meetings of the A.A.V.S.O., I should have no contact with the fraternity of astronomers, excepting by occasional correspondence, but I was happily mistaken. Professor J. A. Parkhurst, who was long engaged at Yerkes Observatory in comparing the visual and photographic magnitudes of important stars, was the first professional astronomer whom I met in the "Sunshine City." He spent a winter here, came at times to the observatory, helpfully counselled me in observing variable stars, and also used the telescope a little in a line of his own research. I greatly prized the friendship of this kind and modest gentleman.

Having decided to get a larger telescope, I was uncertain regarding a number of things connected with so doing, but wholly unexpectedly my need of advice was met by a call at the observatory by Dr. Worcester Reed Warner, designer and maker of the mountings of the world's giant and most perfect refractors. With interest, he examined my half-home-made outfit, assured me that the mounting would carry an 8-inch telescope, indicated ways for improvement, and answered all the ques-

tions about which I had been in doubt. This noted man, in a call of not more than half an hour, gave me help for which I continue grateful. My experiences confirm the belief that professionals in astronomical lines are glad and anxious to encourage and aid amateurs in whatever way they may be able.

Soon after becoming director of Harvard College Observatory, Dr. Harlow Shapley favored St. Petersburg by giving to a large and appreciative audience here, in his brilliant manner, a highly interesting and instructive lecture; opportunity for which I was happy to help secure. The members of the A.A.V.S.O. were at first not sure that they would find in Dr. Shapley such interest and support as Professor Pickering had given. They have found it, and more.

When the class of 1878 was being instructed by Professor Young, there was in Hanover a bright lad who was to become one of America's greatest astronomers. Perhaps Professor Young even then may have caught some vision of this, and may have been planning to lead him towards it. The lad was Edwin Brant Frost, who in "An Astronomer's Life" tells of his intimate relations with the Young family, the children being his playmates, the professor an inspiration, and the home a place where he evidently felt about as free as in his own. In later years, until Professor Young's death, he was at times closely associated with him.

Towards the close of his quarter of a century as director of Yerkes Observatory, and after sight had failed, he and Mrs. Frost began spending their winters in St. Petersburg, and thereby I was given another great privilege in securing his warm and helpful friendship. At the time of my introduction to him, we conversed for nearly half an hour. The next time I called, I spoke, but before I announced my name he had given it. No other whom I have known possessed so remarkable a memory; I looked upon him with wonder. Many a person, if not informed, would not have suspected that he could not see. Once, after Professor Frost had returned, having been absent about seven months, I went immediately to call upon him. He was sitting alone on a piazza. I approached and said, "How do you do, Dr. Frost!" Instantly came his reply: "Why! Mr. Bouton, I am glad to see you." Then, after talking for a few minutes, he told me that just before I arrived a lady reporter from one of the papers had interviewed him; and he added, with a smile, "I don't think she suspected that I could not see her."

One bright evening he came with Mrs. Frost and some friends to the observatory, to talk to them while I turned the telescope to objects he wished them to see. The roof of the observatory rolls entirely off, giving a full view of the sky. Professor Frost felt along the polar axis of the mounting, stepped directly back, and I saw him point to stellar positions as accurately as he could have done, had he been able to see. The heavens were in his mind.

This remarkable ability to hold in mind a mental picture was equally

shown when he lectured. He could accurately announce the position on the screen of any object of which he was speaking. Just once I saw him hesitate. He stated the location of an object, then paused a moment and asked Mrs. Frost, whose custom was to sit near him on the platform while he lectured, "Is that correct?" A gentleman touched me on the shoulder and whispered, "Why does he ask her? Can't he see for himself?" When I whispered in reply, "He is totally blind," the man was astonished.

Though in the field of astronomy there was no higher authority, Dr. Frost did not convince every hearer. As the audience arose at the close of a lecture, two elderly ladies were just before me. One, pointing to the screen, in a high and excited voice exclaimed, "I don't believe a word of it. They don't know anything about it!" Dr. Frost was much amused when I told him of this.

Dr. Frost's field of study was very broad. It was delightful to hear him talk on birds, and to listen to his accurate imitations of their notes.

Nothing more strongly drew me to Dr. Frost, than his unshaken and openly proclaimed belief, that in and through the Universe was Infinite Mind, planning and acting in its development. A Universe originating and unfolding by chance was impossible.

That I have been able to come in a small way into touch with some in what Mr. David B. Pickering has termed the "Astronomical Fraternity of the World" is among my chief satisfactions. It is a goodly fellowship.

St. Petersburg, Florida.

A Search for Physical Changes on the Moon During a Lunar Eclipse

By WALTER H. HAAS

Although it must have been obvious long ago that the passage of the Earth's shadow over the Moon's surface during a lunar eclipse may affect any possible physical changes that occur there, it was apparently not until 1898 that efforts were made to detect such effects.[1] I have summarized elsewhere[2] many of the observations made for this purpose up to 1941. Herein I shall consider the eclipse on August 26, 1942 (dates and times in this paper are by U.T.), listing below those amateurs whose visual observations are known to me. (No photographs of this eclipse good enough to be helpful in the problem stated above have yet been found.) The observers concentrated their attention on certain areas which exhibit, in the course of their lunar days, alterations in appearance that have been ascribed to such physical agencies as lunar vegetation, clouds, snow, etc.[2] In the following table column v represents what is considered to be the relative value of the work of the dif-

ferent observers, judged in accordance with the five criteria given below and the conditions of observation.

Observer and Station	Telescope (s)	v
D. P. Barcroft, Madera, California	6-inch refl., 10-inch refl.	5
C. Cyrus, Lynchburg, Virginia	10-inch refl.	6
C. F. Gramm, Rochester, New York	4-inch refr.	5
W. H. Haas, New Waterford, Ohio	6-inch refl.	10
J. Metzger, Philadelphia, Pennsylvania	6-inch refl.	5
R. V. Shutts, Ardsley, Pennsylvania	10-inch refl.	5
H. Smith, Ardsley, Pennsylvania	10-inch refl.	5
F. R. Vaughn, Plainfield, New Jersey	9-inch refl.	8
L. J. Wilson, Nashville, Tennessee	12-inch refl.	7

In evaluating the likelihood of those changes reported by some of the observers to be caused by the eclipse I sought to find whether the following conditions were fulfilled:

1. The observer was experienced in visual lunar studies.
2. He was well acquainted with the region where he reported the change.
3. The change cannot be readily explained by differing terrestrial atmospherical conditions or by the dimness of the region when near the edge of the umbra.
4. After a while the region tended to regain, or did fully regain, its pre-eclipse aspect. It is here assumed that effects of the shadow's passage are soon dissipated by the rapidly rising temperature of the Moon's surface when the solar rays are again received.[3]
5. Observations close to the date of the eclipse or in other lunations under similar lighting show that the pre-eclipse aspect is the one usually present for the illumination involved and/or that the aspect remarked just after the area reëntered sunlight is not a normal one.

The following times of immersion into the umbra and of emersion from it of various objects were computed with the use of an analytical method derived by Hugh M. Johnson.

Alphonsus was in the umbra from $2^h\,24^m$ to $5^h\,2^m$. Attention was primarily directed to the three main dark spots on the floor. Vaughn noted the same appearance at $0^h\,45^m$ and $5^h\,20^m$, and Gramm saw the same aspect after totality as at $2^h\,10^m$. Haas suspected that the spots were somewhat lighter at $5^h\,9^m$ and at $5^h\,17^m$ than from $1^h\,3^m$ to $2^h\,17^m$ and that they had darkened to normalcy by $8^h\,31^m$. He also suspected a change in their relative intensities. Observations which he made on August 25 and 27, 1942, do not support an eclipse-caused change, which must be regarded as unlikely.

Aristarchus was in the umbra from $2^h\,17^m$ to $4^h\,40^m$. The two most conspicuous of the dark bands on the east inner wall appeared the same to Vaughn at $1^h\,55^m$ and $5^h\,20^m$, and Barcroft thought that the crater possessed its normal aspect near $5^h\,10^m$.

Atlas was in the umbra from $2^h\,53^m$ to $5^h\,13^m$. From $1^h\,15^m$ to $2^h\,50^m$ Haas noted the usual two main dark areas on the floor, one near the south wall and the other in the northwest part of the floor. The latter then had a fainter southern extension, which was joined to the southern area by a faint, narrow, and curving dark band.

At $5^h\ 30^m$ he noted that a change had without doubt occurred since $2^h\ 50^m$. The southern extension had faded almost to invisibility, and the connecting band could not be seen. These alterations are made even more certain by the fact that the seeing was now better than before totality. From $5^h\ 56^m$ to $7^h\ 9^m$ the only change he discerned in the altered markings was a possible slight darkening of the southern extension. At $7^h\ 59^m$ and $8^h\ 41^m$ he recorded that this area was slowly darkening. At $9^h\ 4^m$ it was definitely darker than at $8^h\ 41^m$; and the connecting band was now seen for the first time since totality, even though the seeing was the worst since totality. Indeed, the pre-eclipse aspect was almost reëstablished. Observations by Haas on August 27 and by Robert G. Johnson on August 24 show that the pre-eclipse aspect of the affected areas was the normal one during the lunation of the eclipse. We have here a change caused by the eclipse, one which meets all five of the conditions described above.

Vaughn thought that the southern and northwestern dark areas were each definitely lighter at $5^h\ 30^m$ than at $0^h\ 40^m$. Numerous estimates by Haas between $1^h\ 15^m$ and $9^h\ 4^m$ give no support to such a change.

Haas concluded from a careful study of *Cauchy,* which simulates a peak near full Moon,[2] that the eclipse produced no effect there.

Conon was in the umbra from $2^h\ 34^m$ to $5^h\ 2^m$. There was chiefly watched the "cloud" in the northwest part of the floor.[4] Gramm saw the same aspect after totality as at $2^h\ 12^m$, and Barcroft noted nothing unusual at $5^h\ 50^m$. More weight must be given to the work of Vaughn since he has made a thorough study of this crater; he found that at $5^h\ 10^m$ the "cloud" was smaller than at $2^h\ 5^m$ and had lost its southeast tip since then. A change appears probable.

Haas estimated the intensity of four dark areas in the east half of *Eratosthenes,* which was immersed in the umbra at $2^h\ 26^m$ and left at $4^h\ 56^m$. He suspected that they were somewhat darker at $5^h\ 5^m$ than from $5^h\ 47^m$ to $8^h\ 23^m$ and that their relative intensities underwent some changes. A careful study of all his estimates on August 26 and of some on August 25 and 27 shows that it is unlikely that any change due to the eclipse occurred.

Vaughn observed a dark area near *Firmicus* and another near *Webb;* for them immersion occurred at $2^h\ 54^m$ and emersion at $5^h\ 30^m$ (mean times given). At $0^h\ 52^m$ he found *Firmicus* to be definitely darker than *Webb,* which was equal to *Mare Crisium.* At $5^h\ 35^m$ he made the two dark areas equal and a little darker than *Crisium.* A change in relative intensities appears likely.

For *Grimaldi* immersion came at $2^h\ 3^m$ and emersion at $4^h\ 38^m$. Shutts, Smith, and Metzger agree that some parts of the floor were darker at $4^h\ 35^m$ than before immersion. Normalcy returned near $4^h\ 50^m$ according to Metzger, before $5^h\ 40^m$ according to Smith and Shutts. Barcroft thought *Grimaldi* normal from $4^h\ 35^m$ on but had not observed before

immersion; Gramm drew the same aspect at $1^h\,45^m$ and $4^h\,50^m$ but is inexperienced; Cyrus recorded the same aspect near $1^h\,45^m$ and $4^h\,40^m$ but had poor seeing. A transient darkening of parts of the floor appears very possible.

Cyrus, Smith, and Shutts found no well-evidenced changes in the brightness of the bright spots along the west edge of the crater. Shutts and Smith suspected that one area on the floor was lighter at $4^h\,35^m$ than at $1^h\,25^m$ or at $5^h\,40^m$. Metzger suspected from $4^h\,35^m$ to $6^h\,30^m$ a lack of sharpness of the northeast edge of *Grimaldi* and a lightness of a dark spot west of its north end as compared to his impressions from $1^h\,1^m$ to $2^h\,1^m$.

A dark area in the northwest part of *Hansteen* looked normal to Vaughn 40 minutes after it left the umbra.

Linné was in the umbra from $2^h\,40^m$ to $5^h\,6^m$. The diameter of the white area (*Linné* is seen as such near full Moon) was estimated by comparisons with neighboring objects. Vaughn at $0^h\,35^m$ and Cyrus at $1^h\,40^m$ obtained 5.0 miles. Wilson suspected that *Linné* became smaller and brighter after $3^h\,1^m$. Vaughn at $5^h\,15^m$ thought *Linné* more conspicuous than before the eclipse and now made its diameter 6.6 miles. Haas at $5^h\,20^m$ obtained only 1.5 miles, a discordancy probably due to his taking bounds for the diffusely outlined spot interior to those used by the others. Gramm and Barcroft made no size-estimates; but the former drew *Linné* to be the same at $2^h\,15^m$ and $5^h\,23^m$, and the latter noted nothing unusual near $5^h\,10^m$ and $5^h\,30^m$. A change in *Linné* because of the eclipse appears rather unlikely.

Smith and Shutts observed a dark area on the mountain *Pico,* which was in the umbra from $2^h\,37^m$ to $4^h\,55^m$. Before immersion this area grew darker as it neared the umbra; but as it receded from the umbra after totality, it was absent at $4^h\,55^m$, very faint at $5^h\,2^m$, darker at $5^h\,10^m$, and back to normal by $5^h\,15^m$. A brief lightening because of the eclipse appears possible.

For *Plato* immersion came at $2^h\,39^m$ and emersion at $4^h\,54^m$. This crater looked normal to Barcroft near $5^h\,10^m$ and $5^h\,40^m$. Smith and Shutts thought the rim broader at $4^h\,50^m$ and $5^h\,8^m$ than from $1^h\,25^m$ to $2^h\,45^m$ or from $5^h\,15^m$ on. An actual change appears rather unlikely for physical reasons.

Riccioli entered the umbra at $2^h\,2^m$ and left at $4^h\,36^m$. Attention was restricted to the dark area on the floor. Vaughn recorded the same appearance at $2^h\,0^m$ and $5^h\,5^m$. Cyrus noted the same aspect at $4^h\,35^m$ and slightly later as from $1^h\,10^m$ to $1^h\,25^m$. The dark area looked normal to Barcroft at $4^h\,35^m$ and near $5^h\,0^m$. Gramm drew the same aspect at $1^h\,45^m$ and $4^h\,50^m$; the seeming appearance of a new detail at $4^h\,56^m$ is readily explained by improving seeing. Haas considered the dark area to be the same at $4^h\,40^m$ and $4^h\,45^m$ as from $0^h\,50^m$ to $1^h\,56^m$. At $5^h\,13^m$ he suspected that its south tip was longer than at $4^h\,45^m$, and at

$6^h\ 2^m$ he recorded the tip to be still longer. He thought that the portion which had apparently reappeared continued to darken until *about* $8^h\ 14^m$. The change just described evidently could not have been detected by the other observers. An absence or extreme faintness of the south tip of the dark area just after emersion appears probable, the more so since Haas could not have seen the affected area in the comparatively poor seeing that he had before 2^h.

For *Schickard* immersion came at $2^h\ 8^m$ and emersion at $4^h\ 48^m$. The intensities of the two main dark areas on the floor were estimated by Vaughn and Haas. The latter obtained the same result at $1^h\ 43^m$ and $4^h\ 51^m$. The former found the northern area much lighter relative to the southwestern one at $5^h\ 3^m$ than at $0^h\ 30^m$. The change thus suggested must remain uncertain.

Barcroft alone observed the following objects not long after they re-entered sunlight: *Autolycus, Endymion, Herodotus,* and its environs, a colored area just west of *Lichtenberg,*[2] *Macrobius,* the twin-craterlets *Messier* and *W. H. Pickering,* and a dark area just south of *Zuchius.* He found no abnormal appearances in any of them.

It must be confessed that the data are largely inconclusive and contradictory. It is thought that better results can be obtained in the future if the observers will proceed with greater care and will so plan their work that the third, fourth, and fifth of the criteria can be applied to test reported changes.

It has been seen that at this eclipse at least one change occurred as a result of the shadow's passage. Moreover, it is not probable that *all* the other *possible* changes are illusory. The results of this eclipse give further support to the three conclusions about the effect of lunar eclipses on apparently changing lunar areas that I have already stated.[2] It is worthy of note that in *Atlas* the eclipse-produced alteration lasted for at least four hours after emersion. The probable change in *Riccioli* lasted about three and a half hours. Durations of the other possible changes are very uncertain.

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[4] F. R. Vaughn, *J.R.A.S.C.,* **36,** 49, 1942.

110 N. MADISON STREET, UPPER DARBY, PENNSYLVANIA, FEBRUARY 11, 1943.

The Planets in June, 1943

By ALICE H. FARNSWORTH

NOTE: Greenwich Civil Time is used unless otherwise stated. To obtain Eastern Standard Time subtract 5 hours; Central Standard Time, 6 hours, etc. War Time in each zone is one hour later than Standard. Phenomena are described as seen from latitude 45° N. The *American Ephemeris and Nautical Almanac* is the source of most of the data.

Sun. The Sun starts the month in Taurus ($\alpha\ 4^h\ 31^m.9$, $\delta +21°\ 54'.0$ on June 1) and ends it in Gemini ($\alpha\ 6^h\ 36^m.1$, $\delta +23°\ 11'.1$ on July 1). With its arrival at the solstice, its northerly turning point in declination, on Tuesday June 22 at 7:13, summer begins. Sunspot paths are straight and the solar equator is central on the disk presented to us June 6.

Moon. Phenomena are as follows:

	d	h	m
New Moon	June 2	22	33
First Quarter	11	2	35
Full Moon	18	5	14
Last Quarter	24	20	8
Runs high	5	5	
In Apogee	7	10	
Runs low	19	3	
In Perigee	19	15	

Characteristic of the Full Moon in June and July is its low altitude on the meridian and its rising and setting far to the south of east and west, respectively. Its diurnal path resembles that of the Sun in December.

Mercury moves out to a position 23° west of the Sun on June 18, then draws in closer to it, passing Uranus on June 20 and Saturn on June 30.

Venus, outshining Jupiter by more than two stellar magnitudes, passes 2° north of it on the first day of the month. The two planets are almost directly south of Pollux on that day. Venus continues to move rapidly eastward through the constellation Cancer into Leo where it will be found on June 28, the date of its greatest elongation (45°.4) eastward from the Sun. At this time its phase as seen in the telescope resembles that of the quarter Moon.

In this year when the Copernican quadricentennial is being celebrated, it is interesting to recall that the discovery by Galileo that Venus goes through all the different phases of the Moon was one of the observations that made the Ptolemaic system untenable. In the geocentric situation, it is obvious that Venus, revolving on its epicycle could reveal to the Earth only new and crescent phases, never full or gibbous.

These last two phases, however, are exactly what Venus would be expected to show during the time it was moving beyond the Sun on the far side of its orbit from the Earth as is required by the Copernican system.

Mars continues its eastward progress through the constellation Pisces, easily seen as a "morning star." It reaches perihelion on June 22, the first day of summer in Earth's northern hemisphere. Mars is having summer in its southern hemisphere at the time.

Jupiter's conjunction with Venus on June 1, in the constellation Gemini, is noted above. On that evening, Satellite I is on the disk by the time darkness

comes, its shadow comes in at 1:06, Satellite I leaves at 2:29, and the shadow of Satellite IV comes on at 2:48 almost half an hour before the planet sets.

Saturn, in Taurus, comes to conjunction with the Sun on June 7.

Uranus, also in Taurus, is slightly west of the Sun.

Neptune may be found in Virgo at $\alpha\ 12^h\ 00^m$, $\delta + 1°.5$. It is at its stationary point on June 11, and at east quadrature June 21.

Occultation Predictions for June, 1943

(Taken from the *American Ephemeris*)

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

			IMMERSION				EMERSION			
Date 1943	Star	Mag.	Greenwich C.T.	*a*	*b*	Angle E from N	Greenwich C.T.	*a*	*b*	Angle E from N
			h m	m	m	°	h m	m	m	°
Occultations Visible in Longitude +72° 30′, Latitude +42° 30′										
June 7	ζ Cnc	5.1	0 48.4	+0.1	−2.6	142	1 38.3	−0.4	−0.9	247
7	B.D.+18°1882	6.4	1 39.3	0.0	−1.6	106	2 37.3	+0.3	−1.5	281
11	10 Vir	6.1	23 59.7	−0.8	−2.8	163	1 0.3	−2.5	−0.2	256
15	γ Lib	4.0	23 28.9	−0.7	+0.2	123	0 37.2	−1.3	+0.5	282
16	η Lib	5.6	4 44.5	−1.4	−1.9	142	5 43.9	−1.4	−0.6	249
19	36 Sgr	5.1	8 0.4	−1.3	−0.4	70	9 8.2	−1.2	−1.3	276
21	19 Cap	5.9	3 16.0	−0.1	−0.1	137	3 53.2	−1.2	+2.7	210
21	21 Cap	6.5	6 5.7	−1.7	+0.7	94	7 18.5	−1.7	+0.9	239
21	θ Cap	4.2	9 0.8	−1.9	−0.8	103	10 3.1	−0.8	+0.5	219
30	318 B.Tau	5.7	8 29.1	0.0	+0.4	126	9 4.3	+0.6	+2.6	206
Occultations Visible in Longitude +91° 0′, Latitude +40° 0′										
June 7	B.D.+18°1882	6.4	1 41.6	−0.2	−2.2	130	2 40.5	−0.4	−1.2	261
16	η Lib	5.6	4 25.7	−0.9	−2.6	166	5 9.5	−2.6	+1.0	234
19	36 Sgr	5.1	7 30.8	−1.8	+0.4	65	8 43.5	−1.9	−1.0	287
21	21 Cap	6.5	5 39.4	−1.0	+0.9	102	6 45.2	−1.5	+1.4	239
21	θ Cap	4.2	8 24.1	−2.0	+0.3	91	9 39.0	−1.6	+0.6	236
22	ι Aqr	4.4	9 14.3	..	..	146	9 30.4	..	..	171
27	ξ^2 Cet	4.3	8 51.0	−0.2	+1.7	74	9 53.4	−0.5	+1.8	241
Occultations Visible in Longitude +120° 0′, Latitude +36° 0′										
June 9	ν Leo	5.2	5 36.0	−0.2	−2.1	131	6 34.4	−0.1	−1.3	271
15	13 Lib	5.8	7 28.9	..	..	43	8 0.9	..	..	356
16	190 B.Lib	6.4	2 36.6	−1.1	+1.0	95	3 42.8	−1.0	−0.4	312
17	24 Sco	5.0	2 21.3	..	..	37	2 41.1	..	..	358
19	36 Sgr	5.1	6 33.1	−1.6	+1.0	84	7 47.8	−1.8	+0.2	282
21	θ Cap	4.2	7 35.4	−1.1	+0.9	98	8 43.6	−1.6	+1.4	242
22	ι Aqr	4.4	8 21.6	..	..	141	8 50.0	..	..	189

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

The annual report for our Society for the year 1942 follows. It will be seen that, despite the war, a considerable amount of observing was done by our members and by others who kindly sent in reports. The names of several of our most active observers are either absent or very few meteors are credited to them. In most cases this means that they are in our armed forces. We have a report from only one distant member, Professor Khan in India. Naturally no reports come from our former quite active Japanese members and none from E. Loreta in Italy, who for many years had been one of our best. In previous Notes some remarks have been made about the success of individual groups of observers. It is hoped that such groups will be formed frequently for dates on which important showers are to be expected, as the presence of several persons in the group, all interested and working on the same program, is a stimulating thing. Those who know most can instruct the others in the proper methods of observing and recording. Also a group takes away the loneliness that often comes when working alone at night, particularly if meteors are scarce.

Reprint No. 63 is being distributed to all members who have paid their 1943 dues. It covers all the Meteor Notes of 1942. If any such person has not received his copy by May 1, please notify us. Maps and blanks are, as always, ready to be sent in needed quantities to all working members. Fortunately, the outbreak of war found us with a large reserve supply. As the energies of all persons on the Flower Observatory staff except my own—and mine partially—are wholly occupied in teaching connected with the war effort, I have more work than ever thrown upon me. The reduction of the Meteor Society results inevitably will suffer. The indulgence of our members is asked should anyone feel aggrieved by delays in replies to letters or requests, or in seeing his work mentioned in print. But I beg everyone who can, without neglecting his other duties—particularly any connected with the war effort—that he observe when possible during 1943 so that our work will not suffer too much and we can get a fresh and prompt start to better things when peace finally comes.

The excellent success of the one member of the A.A.V.S.O. (who happens also to be a member of the A.M.S.) who recorded telescopic meteors shows what could be accomplished if any large fraction of the variable star observers would only record those they see. Is there no way of arousing their willingness to aid meteoric astronomy at the expense of so very little time and trouble? For obvious reasons the Hydrographic Office U.S.N. no longer publishes fireball reports. This means a serious, if we trust temporary, loss in our fireball list. We are under many obligations to Harvard College Observatory, to Fels Planetarium, and to Hayden Planetarium all three of which kindly turn over to us reports on meteoric phenomena of all kinds. We also wish to thank the many individuals who have reported for themselves or sometimes for others. I also express my obligations to Miss Edith Reilly, graduate student in astronomy, for preparing the table of results which accompany this article, an undertaking which requires both time and good judgment.

Observer and Station	Nights	Meteors	Remarks*
Anyzeski, Vincent, Hamden, Conn.	1	19	C, P
Aller, Dorothy H., Sierra Madre, Calif.	2	66	C
Anderson, Paul, Beechwood, Mich.	18	434	C, P
Anderson, Russell F., Chicago, Ill.	2	48	C, P; 2 obs.
A.A.F.I., Philadelphia, Pa.	3	109	C, P; 18 obs.
Becroft, Hamden, Conn.	1	10	C, P
Borden, William A., (U.S.A.)	6	44	C
Bowman, Edward F., Kansas City, Mo.	2	229	C; 9 obs.
Braun, M. L., Catawba College	5	656	C; 30 obs.
Brown, R. P., Vancouver, Canada	3	274	C
Copes, William, Baton Rouge, La.	1	32	C, P
Cook, Allan F., Tucson, Arizona	1	23	C
Dole, R. M., Cape Elizabeth, Maine	8	357	C, P
Fonaroff, Leonard, Philadelphia, Pa.	1	12	C
Fortner, Lyman E., Jr., McCormick Observatory, Va.	1	19	C, P; 3 obs.
Gaab, Lalaan, Briceland, Calif.	1	5	C
Gillson, Jane, Hollybak, Dela.	1	11	C, P
Gorson, Robert, Philadelphia, Pa.	2	13	C, P
Graham, Julian W., Salem, Oregon	1	69	C
Gramm, C. F., Rochester, N. Y.	1	29	C
Haas, Walter H., New Waterford, Ohio	1	19	C, P
Halbach, Edward A., Milwaukee, Wis.	1	58	C, P; 7 obs.
Harkens, Yvonne, Lavorika, N. Y.	1	43	C
Horton, William P., Richmond, Va.	2	14	C, P; 2 obs.
Hryse, John, Omaha, Neb.	4	67	C, P
Jewett, Mary L., Grandview, Tenn.	5	68	C
Johnson, Hugh H., Rochester, N. Y.	1	16	C
Johnson, Mach C., Jr., Des Moines, Iowa	15	156	C, P
Khan, Mohd. A. R., Begumpet, Deccan, India	49	234	C
Kneller, George, Catassuqua, Pa.	19	121	C, P
Korneff, Theodore, Burlington, N. J.	1	47	C
Leroy, Steve, Mr. and Mrs., Hamden, Conn.	1	10	C, P
Liller, Bill, Atlanta, Georgia	2	82	C
Louisville Astronomical Society, Louisville, Ky.	3	116	C, P; 6 obs.
Leerman, Joseph, Baltimore, Md.	3	53	C
Marlen, Harold S., East Norwalk, Conn.	1	11	C, P
McCarthy, C. J., Lavorika, N. Y.	1	70	C
McClellan, R., Chino, Calif.	16	394	C, P
McKeon, Mrs. Dorothy D., Titusville, N. J.	1	141	C
Metzger, Jesse, Philadelphia, Pa.	1	16	C, P
Meyrowitz, Benard S., North Branford, Conn.	1	9	C
Milnes, J. N., Oneida, N. Y.	3	39	C, P
Moore, Darrell W., Milwaukee, Wis.	1	21	C
Neale, J. J., Hamden, Conn.	2	15	C, P
Neale, J. J., New Haven, Conn.	2	41	C, P
Olivier, C. P., Lavorika, N. Y.	1	40	C, P
Olivier, Mrs. C. P.,Lavorika, N. Y.	1	19	C
Overmier, Charles, Los Angeles, Calif.	1	33	P
Paterson, J. J., Broken Hill, Australia	1	11	C, P
Parker, Mrs. L. W.,Lavorika, N. Y.	1	46	C
Pottak, Howard, Bronx, N. Y.	—	16	P
Preucil, Frank P., Joliet, Ill.	8	67	C
Rademacher, Mrs. Grace., Hamden, Conn.	2	21	C, P
Roques, Paul E., Los Angeles, Calif.	2	33	C, P
Scott, Paul F., Hamden, Conn.	1	14	C
Shaffer, Frances, Collingswood, N. J.	1	16	C, P
Smith, Claude H., Waterloo, N. Y.	2	9	C, P
Stetson University, De Land, Fla.	1	121	C, P
Stone, David M., Westfield, Mass.	2	10	C, P
Swartz, Robert, Ardmore, Pa.	1	18	C
Tulsa Astronomical Society, Tulsa, Okla.	1	64	C, P; 4 obs.

Observer and Station	Nights	Meteors	Remarks*
University of Oklahoma, Norman, Okla.	3	281	C, P; 7 obs.
University of Oregon, Eugene, Ore.	7	1838	C; 33 obs.
Wagner, David H., Williamsport, Pa.	1	36	C
Warren, Mary K., Hamden, Conn.	1	9	C, P
Woodburn, Joseph, Philadelphia, Pa.	9	37	C
Total		7059	
Telescopic meteors		88†	
Fireballs		99	
Grand total		7246	

*C in this column means that meteors were counted only; P that they were plotted; C, P that some were counted, some plotted.

†72 telescopic meteors were observed by C. W. Fernald at Wilton, Maine, and 16 at Flower Observatory.

We welcome the following new members who have joined since 1941:

McClelland, Robert, California Junior Republic, Chino, Calif.
Spence, C. B., P.O. Box 2014, Ft. Worth, Texas.
Trinn, Miss Maxine, R.R. 4, Aylmer West, Ontario, Can.
Johnson, M. C., Jr., 1118 W. 26 St., Des Moines, Iowa.
Butz, Robert, 248 Park Ave., Lockport, N. Y.
Hryse, John, 2968 Harris St., Omaha, Neb.
Koll, Bob, 2777 California St., Omaha, Neb.
Sember, Michael, 12 Water St., Derby, Conn.
Kneller, Geo., 1112 Second St., Catasauqua, Pa.
Oravec, Edward, 502 E. 77 St., New York, N. Y.
Drummond, S. N., North Western, N. Y.
Gurniout, J. E., 6634 Rue St., Dominique, Montreal, Ont., Can.
Schultz, R. L., R. 2, Box 447, Tucson, Ariz.
Wallace, V. B., 54 Warner St., Wilkesbarre, Pa.
Overmier, Charles, 138 W. 78 St., Los Angeles, Calif.
Wagner, D. H., 1309 Mansel Ave., Williamsport, Pa.
Kiernan, J. W., 3221 Henry Hudson Parkway, Bronx, N. Y.
Henning, E. S., 205 N. Edison St., Arlington, Va.
Knapp, Joseph, 190 Judson Ave., Bridgeport, Conn.
Killion, John, 67 Robert St., Roslindale, Mass.
Fasnacht, Dewey, Jr., 612 Canton Rd., Box 125, Ellet, Ohio.
Hartman, Arnold, 431 S. Buchanan St., Edwardsville, Ill.

Flower Observatory of the University of Pennsylvania, Upper Darby, Pennsylvania, 1943 April 12.

Contributions of the Society for Research on Meteorites

Edited by FREDERICK C. LEONARD
Department of Astronomy, University of California, Los Angeles

President of the Society: LINCOLN LA PAZ, Department of Mathematics, Ohio State University, Columbus

Secretary of the Society: C. H. CLEMINSHAW, Griffith Observatory, Los Angeles, and Department of Astronomy, University of Southern California, Los Angeles

The Eaton, Colorado, Meteorite: Introducing a New Type

By H. H. NININGER
American Meteorite Laboratory, Denver, Colorado

ABSTRACT

This paper contains an account of a 29.547-g. coppery nugget reported to have been observed to fall in May, 1931, at Eaton, Weld Co., Colorado (coördinate number = 1047,405), that the writer is able to explain only on the hypothesis that the specimen is a meteorite of an entirely new type (copper-zinc-lead), coördinate with the sideritic variety (or nickel-irons).

In describing a new and radically different type of meteorite, I am fully aware of my obligation to all astronomers, geologists, and meteoriticists, as well as to the principle of accuracy. Had it not been for this awareness, the present announcement might have appeared some years earlier. My early counselors in the field of meteoritics were the late Drs. O. C. Farrington and George P. Merrill. Both of these veterans were very cautious scientists, and by them I was firmly warned against the danger of trusting too far the factor of human testimony in arriving at conclusions regarding the identity of meteorites. In the course of the past 20 years, I have investigated more meteorites, probably by several hundred per cent, than either of those men. Everyone who has done much investigating in the field of meteoritics has met cases which, as far as human testimony was concerned, appeared to be absolutely sound, yet which, when the material that "had fallen" was examined, were due evidently to a serious error on the part of the observer. Cases of this kind are so common that Dr. Merrill once wrote me, "When it comes to the identification of meteorites, human testimony can never be considered as evidence. The specimens themselves must always supply the answer." This statement I have regarded more highly as the years have passed; yet it is, of course, an overstatement. If human testimony had not been to some extent relied upon in the first place, we should never have known that meteorites exist and we should never have known what characteristics to look for as typical of meteorites. The truly scientific procedure is to consider critically all human testimony, to check it against the charactertistics of the material under consideration, in the light of all other circumstances related to the case, and then to try, without prejudice, to reach a conclusion that is in harmony with all of the known facts. If there is any doubt, it is better to err always on the side of caution. In my files are records of several cases which have never been settled and many others in which apparently honest human testimony has been flatly discounted for the reason that it was inconsistent with the characteristics of specimens or other facts concerned. Altho, as already suggested, I have grown more and more skeptical of human testimony with added years of experience, I have grown also in the conviction that in the realm of meteoritics none of us has adequate knowledge. The very fact that the entire subject remained unknown to science until the beginning of the 19th century is evidence of the difficulty with which facts are gathered in this field. Of this difficulty, not any are so well aware as are those investigators who have ventured forth to explore its precincts in search of new facts with which to advance the study.

In presenting the account which is to follow in this paper, I am confidently expecting to be criticized. Criticism will come from at least 2 groups: first, those whose disposition it is to question any new discovery; second, those who feel that I have held up the publication of the facts here presented, too long. To the first group I have nothing to say; time and continued observation will vindicate the correct view in the long run; I am willing to have the matter rest in the lap of time. To the second group I will say that after 30 years of investigation in

various fields, about 20 of these years in the subject of meteoritics, I have come to be very, very cautious when radically new ideas are concerned. I have held back the facts here presented in the hope that perhaps new facts might come to light, either supporting the case or revealing an error. The case rested too largely at the start on human testimony. I could not then find, however, nor have I since been able to find, any reason for doubting the integrity of the witnesses. There was nothing impossible about, and there was nothing inconsistent in, their testimony. There was one great barrier in the way of my accepting the account at face value: that barrier was the fact that the specimen concerned was so totally different in composition from any known meteorite. Through these years I have waited for some material evidence aside from human testimony to warrant the acceptance of a story simply told, by persons of good reputation, concerning the fall of a meteorite. In the course of the past 20 years, I have dealt with the falls of enough meteorites and with enough witnesses of those falls (certainly well above a thousand witnesses) to know when a story sounds right. This one did. The specimen was right, save in one particular; that particular was its composition! I waited for some additional fact to render more acceptable the admission that a meteorite of heretofore unknown composition had actually fallen. My patience was rewarded. In 1937, a meteorite was found in a Kansas cow pasture which brought me the needed evidence. This stone has been described as the Garnett, Kansas, meteorite.* Fortunately, it was an "orthodox" specimen of the commonest variety in every particular except one; that one particular was its conspicuous content of the one substance which predominates in the specimen which I am now about to describe.

On a bright sunny day in May, 1931, Superintendent John C. Casey of the public schools of Eaton, Weld Co., Colorado, was working in his office in the high-school building, when he was suddenly interrupted by the appearance in his doorway of a neighbor, Mr. W. H. Foster, from the place across the street. The visitor, tho he was a man usually of quiet manner and of few words, was on this occasion evidently somewhat excited and a bit embarrassed, for he had come on a strange errand. The schoolmaster noticed that he was passing from hand to hand a small object, which was being handled as tho it were hot. He inquired as to the cause of this unusual behavior. The object which Mr. Foster carried so tenderly was a small, coppery-looking nugget about 2½ inches long and of a very irregular shape. He explained that it had whizzed past his head like a stray bullet and had struck the ground about 7 feet away. He had been attracted to the humming of the missile some little time before it reached him. He had feared that it might hit him. When it struck with a thud so near by, he looked just in time to see the moist soil of his garden turned up by its arrival. He had been hoeing in the garden when the noise first attracted his attention and he had stood leaning on his hoe while endeavoring to discover the source of the noise. He suspected that the object was a stray bullet from teen-age target practice, but he could remember no sound of gun-fire. When a bright metallic point was seen projecting from the disturbed, moist soil, he stepped over to pick it up. In so doing he averred that he burned his finger, and Superintendent Casey testified that his finger showed a fresh burn half way between its tip and the first joint! The object was recognized by Mr. Foster at once as something

*"Free Copper in a New Aërolite from Garnett, Kansas," *C.S.R.M.*, **2**, 281-4, 1938-41; *P. A.*, **49**, 326-9, 1941.

other than a bullet, but what had been its source puzzled him; naturally, he turned to the Superintendent for an answer. The Superintendent, too, was puzzled. Who wouldn't have been? The science teacher, Mr. Glen Mills, was consulted and he, too, was "stumped." They considered the question of projectiles. They discussed also the possibility of an airplane's burning out a bearing, but all were quite certain that no airplanes had been overhead that morning. As a matter of fact, airplanes were seldom seen over that village in 1931, and their presence always attracted much attention. They discussed the matter of meteorites, but the science teacher was pretty sure that there were no copper meteorites. He consulted the encyclopedia and was convinced that meteorites did not look like copper. Mr. Foster went back to his work, but was greatly puzzled. Fortunately, he took reasonably good care of the object, carrying it in his pocket most of the time.

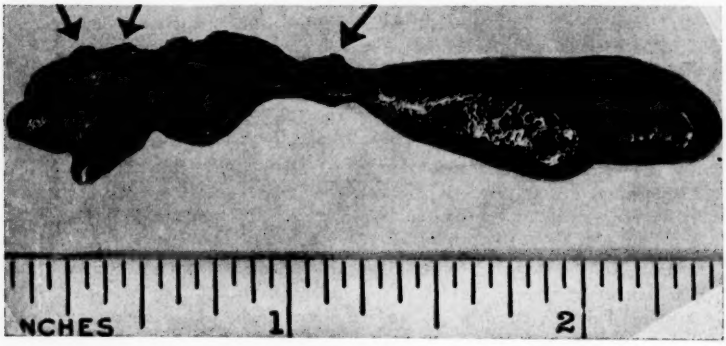


FIG. 1

THE EATON, COLORADO, METEORITE: SIDE VIEW

The front of the meteorite is toward the top of the picture. At the upper left, one may see where the samples for analysis were cut from the rim of an explosion pit. The arrow pointing toward the middle neck indicates where the funnel-like extension was detached for analysis.

It was some 3 weeks later when I met a friend who related the story and asked my opinion. He was assured that no copper meteorites had been known ever to fall and that copper was so scarce in all known meteorites, that there was little likelihood of there being any copper meteorite. Nevertheless, I assured him that the matter would be thoroly investigated. A few days later, I went to see Mr. Foster, accompanied by Mr. Frank Howland, the Curator of Minerals at the Colorado Museum of Natural History, Denver. We found Mr. Foster still in possession of the little nugget. He was quite willing to tell us all he knew about it. We were taken to the approximate spot in the garden where he stood when the missile landed. His story conformed well with that related by my friend. He placed no particular value on the object and was glad to lend it to me for study, setting no time limit, but insisting upon its return when we had finished with it. We consulted the Superintendent, who substantiated everything, insofar as he had been a witness, and who assured us that Mr. Foster had a good reputation in the community.

As my writings testify, I have felt always that students of meteorites are not justified in assuming an air of finality in regard to the possible range of meteoritic composition. This conviction has grown stronger with my years of experience in this field. On the other hand, those same years have deepened my conviction that we cannot exercise too great care in evaluating any report, especially when the report would extend the boundaries of our knowledge regarding this little-known subject. Consequently, I refused to allow myself the luxury of a decision regarding the true significance of this specimen. Try as we would, we could not find any justification for doubting the sincerity of Mr.

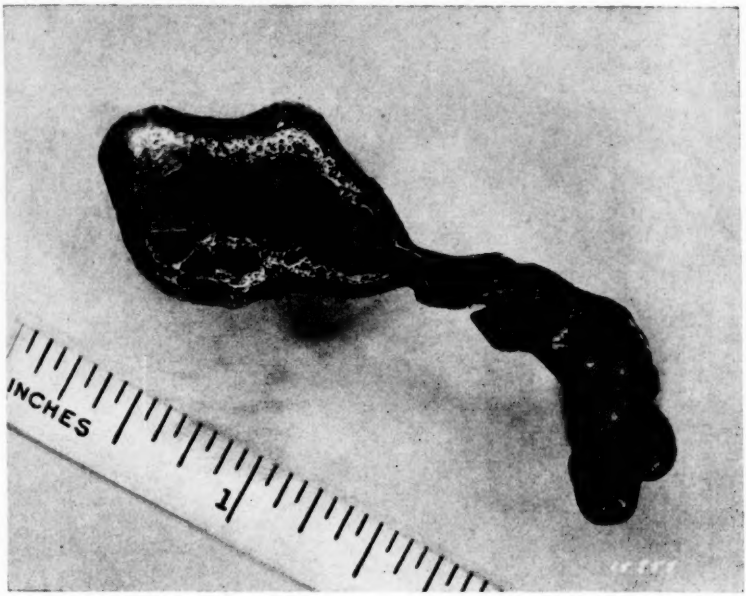


FIG. 2

THE EATON METEORITE: FRONT VIEW

The straight mark near the center of the larger end is a knife scratch.

Foster or the accuracy of his report. He was in no sense a publicity-seeker and he never showed any special interest in the novelty of his experience. Never did he reveal any mercenary interest in the specimen. After keeping it about 2 years, during which time our relations were entirely congenial, tho we saw each other seldom, I persuaded him to sell the object to me, in order to assure that its possible scientific value would not be lost. I told him that it might prove to be a most important specimen, but that I felt no conclusion should be reached regarding it until new corroborative evidence was found. He asked a price of $5.00 for it, which was paid. Because of its extremely radical departure from the known range of meteoritic composition, I decided to devote my greatest effort to an attempt to disqualify the specimen for admission to the extra-terrestrial ranks.

Attempts were made to reproduce its like by the melting of various metals, on the supposition that it might have come from a "burned-out bearing" or from the fusion of some household fixture. 2 of its most impressive features I failed completely to reproduce; one was its strikingly pitted surface and the other was its peculiar shape—particularly 2 funnel-like extensions from a position near its middle, narrow portion.

Another line of investigation was the critical examination of all copper nuggets in mineral collections. Copper nuggets are among the most abundant of mineral specimens. No record was kept of the quantity of nuggets examined, but

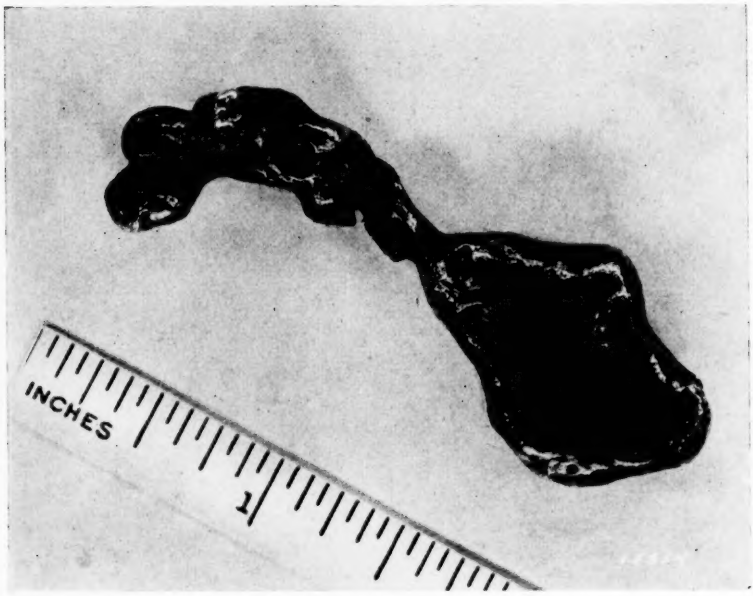


FIG. 3
THE EATON METEORITE: REAR VIEW

the number would run surely into 4 figures. Only 2 cases were found where there was any close resemblance to the surface of the Eaton specimen. One of these specimens came from a puzzling deposit of copper near Tie Siding, Wyoming, where considerable money had been spent years before by persons unknown to me, in an attempt to develop a mine in connection with an abundant surface deposit of large and small copper nuggets. The venture had failed because the copper all seemed to be at or near the surface. No proper mineralization was found in the granite formation where these nuggets lay. The other specimen was a nugget seen in the Butts collection of the Kansas City, Missouri, Museum. This Butts specimen bore a close resemblance to the Eaton nugget, both in general form and in its surface markings; it was, however, several times as large as the latter. The accompanying label stated that this (Butts) specimen had fallen at the feet of

an Iowa farmer many years ago and had buried itself in the soil to a considerable depth (which I failed to record and do not remember). I was promised the opportunity of examining this specimen but, through changes in the curatorship of the collection, the promise had not been fulfilled when the Museum was finally moved to new quarters and the specimen was lost. It seems entirely possible that this specimen might have provided a most valuable bit of testimony in regard to what appears to be a very meaningful question.

Fortunately, the Eaton specimen received good care. Only a few minor scratches marred the original surface markings. Its surface was pitted in much the same manner as are the surfaces of other meteorites of its size, the chief difference being that its pittings are more minute in size. This difference could be due, however, to its lower melting point. The pittings in stony meteorites average smaller in size than do those in nickel-iron meteorites of comparable dimensions. (We may explain here that, other conditions being comparable, the average size of the pittings in meteorites is proportional to the dimensions of the specimens.) The smaller size of their pits is due probably to the stony forms' having a slightly lower melting point. The lower melting point allows for surface liquefaction to persist through lower velocities, when the air-blast has less driving power and hence does not gouge out such broad pits. Copper, having a yet lower melting point than a stony meteorite, would continue to liquefy until the air-blast would be still less powerful and the pits would be correspondingly smaller. Copper is a good conductor of heat. This fact explains the very warm condition of the small nugget when Mr. Foster first touched it. In general, aerolites of comparable size have been quite cold when picked up immediately after arriving on the Earth. The funnel-like extension from the narrow part of the specimen may be explained by the superheating, volatilization, and consequent explosion of a small inclusion of some substance of low boiling point, which occurred when the temperature of the mass became sufficiently high.

Because of the very small size of the Eaton specimen, a complete analysis of it was not made. It was considered more important to preserve the principal mass intact until other and larger specimens of the same type are collected. Final proof of the meteoritic origin of so unusual a type could not rest on composition, anyway. I myself have long regarded surface features as being more truly characteristic than is composition, in the identification of meteorites. Several of our most important stony meteorites, such as Bishopville, South Carolina; Juvinas and Orgueil, France; Pasamonte, New Mexico; Sioux Co., Nebraska; and Johnstown, Colorado, would probably never have been recognized as a result of their composition alone. The Cumberland Falls, Kentucky, aerolite Dr. Merrill himself (probably the most eminent authority of the time) admitted that he refused to believe was meteoritic when he examined the first specimen sent in; however, as additional specimens were found and examined, he discovered convincing evidence of their meteoritic nature. The detection of a meteorite of a new type is far more important than is the discovery of ever so fine a specimen of a common type, provided that it can be definitely demonstrated to be genuine; but every precaution must be taken to avoid an erroneous conclusion. After we had discovered that free copper was present in several meteorites of undoubted genuineness and that a considerable-sized grain of this metal was embedded in the interior of a typical stony meteorite, we could no longer see any sufficient reason for doubting that a nugget of pure copper, or of copper alloyed with other metals which are commonly associated with it in nature, could exist. Had the

Garnett, Kansas, specimen not been discovered, I should still feel compelled to submit the Eaton specimen as a problematical meteorite, but now that we positively know that metallic copper does sometimes occur in the commonest variety of recognized meteorites, the existence of coppery meteorites is logically to be expected. Let us suppose that an otherwise typical aerolite contains one or more nuggets of copper of whatever size when it enters the atmosphere. As it undergoes the usual process of frictional ablation and the terminal disintegration which characterizes the arrival of aerolites in the lower stratosphere, we should expect that the brittle and perhaps friable stony matrix would be reduced to dust, while the tough, ductile copper would have a chance to survive. Of course we might assume also that a copper-zinc-lead alloy could be formed independently of any stony matrix, just as the nickel-iron alloys have been formed into meteorites (however, whenever, and wherever that process has taken place). In short, we may, I think, henceforth incorporate into our classification of meteorites the copper-zinc-lead group, coördinate with the nickel-irons (or siderites).

No light phenomena are recorded as having accompanied the fall of the Eaton specimen. If any were noted, they were not reported to me. Mr. Foster stated that he did not see anything of the kind. The school men, to whom the fall was immediately reported, were, of course, inside the school building and had no opportunity to see any such phenomena, had there been any display. No sound was noted by Mr. Foster, other than the whizzing of the missile. This fact is not strange, however, because frequently those who witness the fall of a *small* meteorite fail to associate the blast-like detonation, coming from the stratosphere, with the falling of the small body landing near them, especially since the 2 phenomena do not occur usually at the same instant. The absence of any report of light phenomena is not without precedent. Those near whom the Warrenton, Missouri, aerolite of 1877 fell declared that they saw no light from it, even tho they were in an open field. This stone was seen as a dark object passing through the lower regions of the atmosphere. Its weight was estimated at 100 lbs. from the fragments which were scattered over the snow when it crashed into a tree. As fas as I know, no light phenomena were reported by members of the community in which the Benld, Illinois, stone fell, penetrating a garage roof and an automobile, in 1938. Several other authentic falls have not had associated with them any known light phenomena.

In the case of the Eaton fall, we made no effort to elicit reports from the public, for 2 reasons; first, 3 weeks had elapsed without any public notice being given to the event, so that, even if reports had been secured, in answer to a request from us, we could have been hardly certain that they related to the same event; second, any publicity would have, almost surely, carried a reference to the unique character of the specimen and would thus have evoked comment which would have rendered difficult a cool and unprejudiced decision as to the origin of the specimen. There are some reasons, aside from any consideration of the Eaton fall, for believing that, under certain conditions, meteorites may reach the soil without producing, in the course of their flight, the usual light and sound phenomena that are commonly such a conspicuous feature of their arrival. This question has for several years been under critical consideration by me and, I think, by some other students of meteorites.

The Eaton specimen is preserved in the Nininger collection and shall be known as the Eaton, Weld Co., Colorado, meteorite (coördinate number = 1047,-405). Its original weight was 29.547 g.

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Recorder

Notes on W Ursae Majoris Stars: Two recent papers by Dr. Edith Jones Woodward in the *Harvard Circulars* give some interesting and important facts about eclipsing binaries of the W Ursae Majoris type.

The first paper deals with four of these stars, W Ursae Majoris, AK Herculis, VW Cephei, and SW Lacertae. For W Ursae Majoris itself, all available material was discussed, together with some very carefully planned and well executed photographic observations by the author. The photographic observations were made with a 3-inch Ross photographic telescope at Mount Holyoke College in the winters of 1938, 1939, and 1940. Excellent light curves are shown, both with individual observations and mean values.

A study of the time residuals of minima reveals an apparently abrupt change in period about 1900, when it seems to have begun to decrease. This change in period seems real in spite of the very small difference before and after 1900, only $0^{d}.163$ per period.

W Ursae Majoris is an optical double with a $13^{M}.1$ component $7''.0$ distant. The mean trigonometric parallax is $0''.020$, therefore the absolute magnitude of the system at maximum is $+4^{M}.64$, and of each component separately, $5^{M}.19$ and $5^{M}.65$. Mount Wilson observers reported that two spectra are visible, with extraordinarily wide and diffuse lines, and a maximum velocity of about 330 kilometers per second.

The mean difference in magnitude at the two minima is very small, $0^{M}.03$ when measured photographically and visually, and $0^{M}.05$, photoelectrically. Therefore, the components are not exactly the same in surface brightness. All observations at maximum appear to indicate that the first maximum is slightly brighter than the second, by $+0^{M}.04 \pm 0^{M}.01$. This difference could be explained by the fact that the surfaces of one or both components are not symmetrically illuminated, or that the orbit is eccentric and reflection effects vary at the two maxima.

A picture of this star is given with the bright component of an optical double showing light variations which indicate that it is an eclipsing binary with a period of one-third of a day. The perod has slowly decreased since 1900. The two dwarf components are separated by 1.5 million kilometers and revolve about one another in a probably circular, or nearly circular, orbit. The two stars are slightly smaller than the Sun, one having about 0.7 the radius of the other. The larger star is twice as luminous as the smaller, but both are of about equal surface brightness. The two stars are slightly less massive than the Sun, but they are two or three times as dense as the Sun. There is some evidence that the light variations do not exactly repeat themselves between cycles, and therefore the major axes of the two distorted bodies are not in line.

AK Herculis was also studied in a similar manner by Dr. Woodward from photographs taken in 1939 and 1941. Normal light curves for each year are shown. The star was also measured on nearly 4,000 plates of the Harvard collection. AK Herculis is the brighter component of a visual double, the fainter component

being of the twelfth magnitude. An examination of the elements of the period indicates a slight decrease in the value. It may be that AK Herculis has an eccentric orbit and that the line of apsides is in fairly rapid rotation.

VW Cephei, the third star observed, is one of the brightest of the W Ursae Majoris variables and with a short period, namely $0^d.278$.

No well-determined published curve of the star was available heretofore. Dr. Woodward made 450 photographic observations, as in the same manner for W Ursae Majoris.

Mt. Wilson observers described the lines as probably double, with intensity ratio of the components two to three. The spectrum was classed as G4p. Yale and Greenwich give the trigonometric parallax as $0''.044 \pm 0''.013$. If the apparent maximum magnitude is assumed to be $8^M.05$, then the absolute magnitude of the system is $6^M.27$ and of the individual components, $6^M.38$ and $6^M.42$. The system has a large annual proper motion of $0''.632$, not inconsistent with the dwarf character of the components and the large parallax.

There is some evidence that the light curve varies from cycle to cycle, and that the two maxima are almost certainly not of the same brightness, and there is some indication that the descent to minimum is more rapid than the ascent.

In 1940 Dr. C. Payne Gaposchkin concluded that VW Cephei had a continuously changing period which could be satisfied by a sine curve in a period of 28.76 years and an amplitude of $0^P.064$, and accordingly, if the changing period is caused by revolution about a third star, that star is probably as bright as or brighter than the components of the eclipsing pair.

A normal light curve of over a thousand observations by Walter and Woodward is shown.

The fourth star studied is SW Lacertae. Dr. Woodward gives a light curve derived from her 175 photographic observations in 1939. There is also shown a curve by Nijland for the years 1920-1924. These two curves show some differences in shape, the Woodward curve showing wider primary and secondary minima. SW Lacertae has an observed parallax of $0''.016$ and a proper motion in R.A. of $+0''.069$.

There is doubtless a changing period for this star, perhaps a cycle is completed in about 50 years. The star is pictured as possibly a pair of dwarf stars, similar to the Sun, which revolves in an orbit of small eccentricity, in a period of $0^d.32$. The two components are practically in contact. The eclipsing pair appears to revolve about a third star once every fifty years, with the major axis of the small orbit always approximately perpendicular in the plane of the large orbit to the line joining the eclipsing pair to the third star.

In the second paper Dr. Woodward has made a statistical study of W Ursae Majoris stars in general, with some interesting conclusions. In the first place she defines a W Ursae Majoris star as an eclipsing binary whose light curve between eclipses is conspicuously convex upward with periods less than $1^d.5$, whose spectrum, if known, is later than A0, and with a range of secondary minimum greater than two-thirds the range of primary minimum.

It is pointed out that care must be taken to avoid classifying cluster-type Cepheids as W Ursae Majoris stars. The cluster-type light curves are usually somewhat asymmetrical and the minima are at least as wide as the maxima. W Ursae Majoris stars are dense solar-type dwarf systems. There are listed 117 stars of the W Ursae Majoris type and 33 which are probably of this type. For

the 117 stars orbital elements as estimated from the light curve are given.

Following are some of the characteristics of W Ursae Majoris stars:

The two components are very nearly equal solar-type dwarf stars of rather high density and elliptical shape.

They are scattered in all galactic latitudes and longitudes.

The mean period is $0^d.48$, with greatest frequency of period about $0^d.38$.

There are very few bright members, the average apparent magnitude being $11^M.84$.

Following is a list of other average values for these stars:

Range at primary	$A_1 = 0^M.65$
Rectified primary range	$A_1{}^r = 0^M.36$
Inclination	$i = 74°$
Ratio of Radii	$k = 0.88$
Ratio of surface brightness	$v = 1.1$
Density	$\rho = 1.5$
Absolute magnitude	$M = +4^M.6$
Ellipticity of stars	$b/a = 0.76$
Ellipticity constant	$Z = 0.34$

A picture of W Ursae Majoris stars in general is given by supposing the systems to be pairs of stars of spectral type G, with nearly equal radii and surface brightness, and of density slightly greater than the Sun, as elliptical bodies almost in contact as they revolve about their common center of gravity in half a day.

One of the most interesting of these stars is 44i Bootis which is a component of a visual binary having a period of 219 years. 44i Bootis has a changing period which shows the inclination of the visual orbit to be $+83°$. The eclipsing binary has a range in variation of $0^M.6$, but when close to its companion the range of the combined light of the three stars in only $0^M.1$.

A list of W Ursae Majoris stars is given for which many more observational data are needed; these include, among others, S Antliae, RR Centauri, V502 and V508 Ophiuchi, U Pegasi, and W Ursae Majoris.

Nova Puppis: This remarkable nova can still be well observed, especially in the southern hemisphere. It remains between the sixth and seventh magnitudes, with evidently little change in brightness.

Due to misinformation received by the Recorder, credit for the independent discovery of the nova on November 8, 1942, was given in these notes to Mr. C. L. Segers. Mr. Segers now informs us that he made an error in transposing civil date to Julian date and that he first observed the nova on November 9. Accordingly it is to Dr. B. H. Dawson of LaPlata that the credit of being the original discoverer goes, and he is therefore entitled to receive the David B. Pickering Nova Medal of the A.A.V.S.O.

The R Coronae Borealis Stars: R Coronae Borealis is nearly back to normal maximum brightness, magnitude 6.0.

SU Tauri is still faint, below the 13th magnitude.

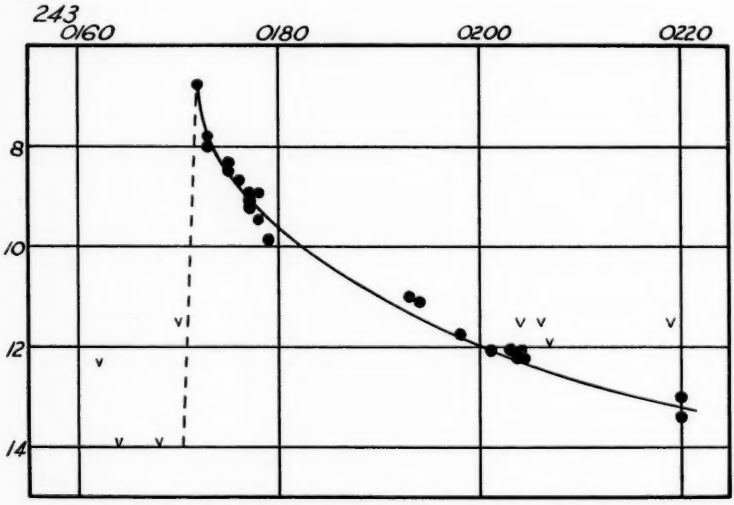
RY Sagittarii is apparently slowly increasing to its normal maximum magnitude, between the sixth and seventh.

Observations just received as made in January by R. P. de Kock at the Royal Observatory, Capetown, indicate that the long-expected drop to minimum of S Apodis was under way. The decrease began late in December and by January 16 the magnitude had reached 12.2—normal maximum, 10.1.

Another Nova in Sagittarius: In the examination of a recent shipment of plates from South Africa, Mrs. Margaret L. Mayall has found another interesting bright nova in the constellation of Sagittarius located in R.A. $18^h\ 19^m.2$, Decl. $-35°\ 5'$ (1900). The nova was detected from a spectral image shown on a plate taken on July 18, 1941, and confirmed on another spectrum plate of July 29. They showed broad emission bands for the hydrogen lines Beta to Zeta.

Chart plates of the region indicate that the nova attained the magnitude 6.8 on June 26, while on a rather poor plate of June 24 no trace of the star could be seen. Pre-maximum magnitude was less than $16^M.0$.

The photographic light curve as determined by Mrs. Mayall is shown in the figure.



PHOTOGRAPHIC LIGHT CURVE OF NOVA SAGITTARII, 1941

This most recently discovered nova has a light curve typical of many of those found in Sagittarius; a very rapid rise, sharp maximum and fairly speedy decline to minimum. The star faded six magnitudes in seven weeks, very rapidly at first, but more slowly at the end.

Sagittarius, in the heart of our own galaxy, is certainly a real hunting ground for novae. The total number found there exceeds twenty, possibly it numbers twenty-five or twenty-six, nearly one-fourth of all known galactic novae.

Observers and Observations, March, 1943:

Name	Var.	Obs.	Name	Var.	Obs.
Blunck	12	13	Garneau	7	7
Boone	9	9	Harris	25	25
Bouton	29	35	Hartmann	89	105
Buckstaff	7	7	Hiett	9	16
Carpenter	2	2	Howarth	16	18
Dafter	8	18	Kearons	73	150
Duffie	15	17	Kelly	16	19
Fernald	137	213	de Kock	49	282

Koons	30	37	Rosebrugh	16	55
Maupomé, E.	26	31	Sill	25	25
Mayall	1	12	Topham	9	10
Nadeau	43	49	Vohman	16	28
Palo	24	43	Webb	12	13
Parker	23	23	Weber	40	40
Parks	17	30	—		—
Peltier	103	148	31	Totals	1480

April 15, 1943.

Comet Notes

By G. VAN BIESBROECK

In the course of the last month there have been no new cometary discoveries.

COMET 1942 *f* (WHIPPLE) has continued its slow course through the constellation of Ursa Major and is now crossing the Hunting Dogs. It has remained unexpectedly bright and, even when last recorded here (April 9), it was still visible with the naked eye, the total brightness being estimated as equivalent to a star of magnitude 5.3, while the predicted brightness was nearly two magnitudes fainter. This makes it the fourth month of naked-eye visibility. On that same night (April 9) I estimated the diameter of the coma as 6 minutes of arc and there was still a coarse tail pointing nearly in a southern direction. However aside from some jets near the bright nucleus, the tail no longer shows the detailed structure mentioned previously (p. 153).

No ephemeris is available at this moment, but the object can easily be picked up with binoculars and will presumably be followed yet for several months.

COMET 1942 *e* (OTERMA) can now only be seen in large telescopes. It has faded more rapidly than was indicated by the ephemeris on p. 154. On April 9 I estimated the magnitude as 15. The comet showed a faint nucleus with a little fan-shaped tail pointing eastward. It will be followed for sometime longer as it is conveniently located near Gemini.

Several faint periodic comets are due to return in the first half of this year: COMET NEUJMIN II, COMET REINMUTH, and COMET D'ARREST. My efforts in locating these inconspicuous objects have not met with any success so far.

McDonald Observatory, Fort Davis, Texas, 1943 April 10.

General Notes

Dr. H. Spencer Jones, Astronomer Royal, has been awarded the Gold Medal of the Royal Astronomical Society for his determination of the solar parallax. (*Nature*, March 20, 1943.)

Miss Elizabeth Bond of Cambridge, Massachusetts, died on April 12 in her ninetieth year. She was the granddaughter of William C. Bond and daughter of George P. Bond, first and second directors of the Harvard Observatory. Miss Bond was the sole honorary member of the Bond Astronomical Club, founded in 1924 in honor of William C. and George P. Bond.

Miss Lois T. Slocum has left Smith College, where she was Assistant Professor of Astronomy, and has taken up work at the Radio Research Laboratory at Harvard University.

Professor Frederick Slocum, Director of the Van Vleck Observatory at Wesleyan University, gave a lecture at Smith College on April 13 on the subject "Copernicus and the Changing Picture of the Universe" as part of the celebration of the 400th anniversary of the death of Copernicus.

Dr. Otto Struve, professor of astronomy and astrophysics in the University of Chicago, and director of the Yerkes Observatory, was elected a vice-president of the American Association for the Advancement of Science, chairman of the section on astronomy. Election for officers for the Association were held this year by mail because, the annual meeting having been canceled, the election could not be held in the usual way.

James Richard Jewett

On March 31, James R. Jewett, professor emeritus of Arabic at Harvard University, amateur astronomer and patron of astronomy, died in Cambridge at the age of 82. It was Professor Jewett who sponsored Harvard's 24-33-inch Schmidt-type telescope (which inspired the Tonanzintla instrument). His own 9-inch Clark refractor with clock drive and housing he also donated to Harvard where it fills a great need in the instruction and entertainment of visitors, especially on "school nights." A close friend of Annie J. Cannon, he supported the publication of much of her work, his last gift making possible the publication of an Annie J. Cannon Memorial volume which will contain Miss Cannon's work that was unpublished at the time of her death two years ago. Professor Jewett was a life member of the American Association of Variable Star Observers, to whom he presented a 5-inch telescope.

Although his name is not affixed as author to any astronomical publications, Professor Jewett will long be affectionately remembered at Harvard as one of its staunchest friends. His name will always be associated with the work accomplished through the telescopes with which he enriched the observatory.

DORRIT HOFFLEIT.

Harvard College Observatory.

Meeting of the American Astronomical Society

Upon the invitation of Dr. Harlow Shapley, the seventieth meeting of the Society will be held at Harvard College Observatory, Cambridge, Massachusetts, May 28-30, 1943.

TENTATIVE PROGRAM

Friday, May 28

2:00 P.M.—Registration of members begins, Building D, Harvard Observatory.

4:00 P.M. Teachers' Conference, Building D.

Evening: Council dinner and meeting; informal gathering of members at the Observatory.

Saturday, May 29

Morning: Session for papers, Building D.

Noon: Society photograph.

Afternoon: Business meeting; session for papers.

7:00 P.M. Society dinner, Harvard Faculty Club, 20 Quincy Street, $1.50.

Sunday, May 30

Morning: Probably a Council meeting and a session for papers.

Copernican Quadricentennial

The movement indicated by the above title is fostered by the Kosciuszko Foundation, with national headquarters in New York City. The Foundation was established in 1925, and is named in honor of General Thaddeus Kosciuszko, Polish patriot and American Revolutionary war hero. The avowed purpose of the Foundation is the "promotion of cultural relations between the people of the United States and Poland." Since 1925, the Foundation has exchanged 168 students, research scholars, and professors between Polish and American institutions of higher education, has expended $122,000 in scholarships, and has been instrumental in the publication of a number of books on cultural topics pertaining to these two countries.

Recent world events have made the desirability and the necessity for such a Foundation immeasurably greater than the organizers of it in 1925 could forsee. Stimulated by the emergency and favored by an important anniversary, namely, the four-hundredth of the death of Copernicus, the greatest scientist Poland has produced, the Foundation has greatly increased its activities. During this month of May, hundreds of the foremost colleges and universities in the United States and Canada will present special programs in honor of Nicholas Copernicus. The oldest university on the American continent, namely the University of San Marcos at Lima, Peru, founded in 1551, only eight years after the death of Copernicus, is one of these.

The several planetariums also are participating. Their equipment lends itself admirably to the demonstration of the basic ideas with which the Copernican theory is concerned.

Cooperating committees have been appointed in twenty-nine of the states, these committees consisting of the leading persons in science and education.

Three states, New York, New Jersey, and Pennsylvania, will observe May 24 officially as Copernicus Day in accordance with recent action taken by the State Legislatures. Many cities also have appointed local committees which are arranging programs of cultural and scientific tribute appropriate to the plans of the Foundation.

The climax of the several programs will be reached in the Copernican Quadricentennial commemoration which will be held in Carnegie Hall, New York City, on the evening of May 24. Dr. Harlow Shapley, Director of the Harvard College Observatory, and national chairman of the Quadricentennial committee, will preside at these exercises, leading scientists from many parts of the nation will pay tribute to Copernicus and his discoveries, and a message pertinent to the occasion, broadcast from London, will be heard.

We hope to have the next issue of POPULAR ASTRONOMY as a special Copernican number.

Science Talent Search Scholarships Awarded

Gloria Indus Lauer, 17, from Ames, Iowa, and Ray Reinhart Schiff, 16, from New Rochelle, N. Y., recentiy received the top awards—four-year Westinghouse Science Grand Scholarships worth $2,400 each—at the close of the nation-wide

second annual Science Talent Search. Both are high school seniors.

They were chosen by a board of judges for the highest awards given to the 40 student delegates who attended a five-day Science Talent Search Institute. Eight of the other young delegates received four-year Westinghouse Science Scholarships worth $400 each and 30 were awarded one-year Westinghouse Science Scholarships of $100 each.

The awards were made by Dr. Harlow Shapley, Director of the Harvard College Observatory and Chairman of the Science Talent Search board of judges, at a banquet at the Hotel Statler in Washington, D. C. The banquet closed the four-month long quest for the students of the greatest scientific talent among the high school seniors of America.

$11,000 in Scholarships

Total of the scholarships awarded in the Science Talent Search sponsored by the Science Clubs of America and the Westinghouse Electric and Manufacturing Company is $11,000. All of the scholarships permit the recipient to attend any college or university of his choice that meets requirements of the scholarship awarding committee. The awards do not prevent the young scientists from accepting other scholarships that may be offered to them as a result of their showing in the Science Talent Search.

Miss Lauer, who plans to major in college physics after finishing high school, is a talented musician. A violinist, she won first place in a state music contest, and has played in the Iowa State College Symphony for five years. She is a self-taught typist, excels in the use of the slide rule, can operate a simple lathe, drill press and band saw, and once devised a test for rating the best potential trainees in an automobile training program.

Young Schiff, a member of the National Junior Honor Society, ranks first in his graduating senior class of 250. He has tutored others in mathematics, physics, Latin, and English, and learned practical skills last summer while serving as a counsellor at a boys' camp. He has spoken at two teachers' conventions, and won first place in an oratorical contest sponsored by the American Legion. He plans to study nuclear physics.

Eight Awarded $400 Scholarships

Those who received the four-year $400 Westinghouse Science Scholarships are:

Charles Poultney Perot, 17, J. P. McCaskey High School, of (712 Race Avenue) Lancaster, Pa.

Thomas Richard Quermann, 17, Washington Irving High School of (132 Hall Street) Clarksburg, W. Va.

Josiah Macy, Jr., 17, St. Paul's School, Concord, N. H.; home: Summerfield Farm, Warrenton, Va.

Donald Rosswell Harris, 17, Central High School, of (315 McMillen Street) Johnstown, Pa.

William Weidman Piper, 17, Grandview Heights High School, of (1858 West First Avenue) Columbus, Ohio.

Henry Hiram Kohl, 16, Phillips Exeter Academy, Exeter, N. H.; home: 359 Montgomery Street, Newburgh, N. Y.

Elizabeth Ann Lean, 17, Shorewood High School, of (4341 North Woodburn Street) Shorewood, Wis.

Virginia Ellen March, 16, West High School, of (4001 Mineral Point Road) Madison, Wis.

One-year Westinghouse Science Scholarships worth $100 each were awarded to thirty others scattered through twelve states.

Book Reviews

Odd Numbers, or Arithmetic Revisited, by Herbert McKay. (The Macmillan Company, New York. $2.00.)

In the April (1941) issue of this magazine we reviewed this volume. In January, 1943, an American Edition of this work was issued by the above-mentioned Company. In the former review it was stated that the book contains much of interest to any intelligent person even though he may not be specially trained in the lore of numbers. Many surprising properties of numbers are set forth and many relations not suspected are shown to exist among them. Any one who will take the time to comprehend the comparatively simple discussions will be amply repaid for his efforts. C.H.G.

Atoms, Stars, and Nebulae, by Leo Goldberg and Lawrence H. Aller. (The Blakiston Company, Philadelphia, 1943, 323 pp. $2.50.)

The fifth of the admirable Harvard Books on Astronomy comes at a time when nothing short of a genuine contribution justifies the appearance of a new book. "Atoms, Stars, and Nebulae" is particularly welcome, however, because it presents areas of greatest importance in current astronomical investigation, many of which have not been made easily accessible to the layman. The modest size of the volume seems hardly in keeping with the magnitude of the scope of the title. But as a descriptive handbook of astrophysics this work will provide much to stimulate not only the astronomical reader but the observer who will find new meanings in already familiar objects.

After a brief introduction to the stars and nebulae, the authors review the principles and applications of spectroscopy, including a chapter on atomic and molecular structure. Then follows a discussion of the conditions obtaining in stellar atmospheres, with descriptions of the dwarf, giant, and supergiant stars. One of the most valuable features of the book is the excellent treatment of the formation of the absorption lines, the theoretical and observed "curves of growth" and the factors influencing line profiles and the opacities of stellar atmospheres.

The subject of variable stars is well reviewed, but from the point of view of "exclusive" material, the section on planetary nebulae is more conspicuous. Astrophysics is in its finest fettle in the interpretation of the spectra of the intriguing gaseous nebulae and related problems. The story of the mystery of nebulium is one of the classics of science. This reviewer, however, feels that it is not complete without Russell's quip about the vanishing of nebulium into thin air.

A discussion of stars with extended atmospheres constitutes another high spot (or perhaps plateau) of the book. Much valuable information is given about the Wolf-Rayet, P Cygni, B emission stars and novae, with their puzzling correlations. The concluding chapter deals with the source of stellar energy. Additional information concerning physical quantities, radiation, stellar magnitudes, and ionization formulas is given briefly in the appendices. Observers will be interested in the catalog of planetary nebulae visible in small telescopes.

The attractiveness and the careful editing of the *Harvard Books* on Astronomy are too well known to need further comment. The book by Goldberg and Aller is finely illustrated, although in some cases the explanations of the figures are perhaps insufficient. For example, under Fig. 29, a spectrogram of iron,

the statement is made that "the plates are taken with a rotating sector to show weak and strong lines in the same exposure." The reader may want to know how a rotating sector can produce a differential weakening of the lines. Figure 75 (also reproduced in another volume of the series) shows a photograph of the nebulosity around R Aquarii, and a startlingly different drawing made from the same photograph, with no explanation of the discrepancy, or the purpose of the drawing. The caption of Fig. 127 should read "Profiles of the Stars of the P Cygni Type," and the page number of the reference is in error. A footnote on page 7 repeats the error that the brighter stars within each constellation are labelled with the letters of the Greek alphabet in order of decreasing brightness. These are matters of little consequence. "Atoms, Stars, and Nebulae" will rightfully find a place in any astronomical book shelf.

W.A.C.

Carleton College.

Publications Received.—The publishers of POPULAR ASTRONOMY hereby acknowledge receipt of the following named publications and express their great appreciation of the courtesy shown on the part of those who have sent them.

Publications of the University of Michigan:

Vol. VIII, No. 12. "On the Spectra of Novae," by Dean B. McLaughlin.

Annals of the Astronomical Observatory of Harvard College:

Vol. 109, No. 2. "Variable Stars in MWF 361," by Emily Hughes Boyce.

Vol. 113, No. 1. "The Variables of RV Tauri Type," by Cecilia Payne-Gaposchkin, Virginia K. Brenton, and Sergei Gaposchkin.

Harvard College Observatory Circulars:

No. 446. "A Study of Four W Ursae Majoris Stars," by Edith Jones Woodward.

No. 447. "Statistical Study of W Ursae Majoris Type," by Edith Jones Woodward.

No. 448. "The Spectra and Absolute Magnitudes of Bright M-Type Stars," by Dorrit Hoffleit.

Harvard Reprints:

No. 246. "On the Material Ejected from Novae," by Cecilia Payne-Gaposchkin and Sergei Gaposchkin.

No. 247. "On the Dimensions and Constitution of Variable Stars," by Cecilia Payne-Gaposchkin and Sergei Gaposchkin.

No. 248. "A Study of the RV Tauri Variables," by Cecilia Payne-Gaposchkin and Virgina K. Brenton.

No. 249. "Galactic and Extragalactic Studies. XVI. Photographic Amplitudes of Classical Cepheids," by Harlow Shapley.

No. 250. "Variable Star Notes from the American Association of Variable Star Observers in 1942," by Leon Campbell, Recorder.

Harvard Reprint Series II:

No. 1. "Theoretical Light Curves of Close Eclipsing Systems," by Zdenek Kopal.

No. 2. "Variable Stars and the Sources of Stellar Energy," by Cecilia Payne-Gaposchkin and Sergei Gaposchkin.